Understanding socioeconomic disparities in breastfeeding in the UK: Exploring the role of environmental quality

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DECLARATION

I, Laura Jessica Brown, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

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Date:

ABSTRACT

Guided by the evolutionary framework of life history theory, which predicts lower parental investment in lower-quality environments, my PhD research explores socioeconomic differentials in breastfeeding behaviour in the UK with a particular focus on local environmental quality. My research is quantitative, and I use advanced statistical techniques to analyse two large UK cohort datasets: the Millennium Cohort Study (MCS) and the Born in Bradford (BiB) cohort. The thesis is comprised of three papers. The first paper compares objective and subjective summary measures of the local environment, using factor analysis to pull together both physical and sociocultural aspects. Using multi-level modelling on nationally-representative data (the MCS), I isolate the effects of the local environment above and beyond that of individual socioeconomic status (SES) and wider-scale deprivation and other ward-level factors such as ethnic composition. I find that objectively-assessed environmental quality is a more robust indicator of breastfeeding initiation and duration than subjectively-assessed environmental quality and also that higher individual socioeconomic status provides a buffer, protecting the breastfeeding chances of those with more resources, even in low quality environments.

With Paper 1 providing a UK-wide picture of the relationship between environmental quality and breastfeeding, my second paper zooms in on one geographical region in particular. In Paper 2 I use the BiB dataset, with its largely bi-ethnic Bradford population to look at the influence of the physical environment (e.g. air and water pollution) on breastfeeding outcomes and whether there are differences between White British and Pakistani mothers. I use structural equation modelling to explore whether associations are mediated by birth outcomes. I find the predicted negative association between SES and breastfeeding, but no strong or consistent evidence for the same relationship when physical measures of environmental quality are used. Paper 3 uses both datasets to situate breastfeeding within a wider suite of reproductive behaviours and demographic and health traits including other parental investment measures, menarche and age at first birth and uses latent class analysis to test whether these characteristics cluster together to form identifiable life history strategies along an environmental quality continuum.

This thesis examines the local environment in detail, operationalising environmental quality in different ways, to see whether environmental quality is an important driver of the SES-breastfeeding association in the UK. Overall, the thesis findings suggest that individual SES is a stronger predictor of breastfeeding than environmental quality, but that the two are strongly linked, and exert their own independent effects. The effects of the local environment are however complex and depend on which indicators of environmental quality are used. Associations are not driven by individual environmental perception as much as they are by more objective measures of environmental quality. Less perceivable, more physical measures of environmental quality do not explain the SES-breastfeeding association, suggesting that in the UK context at least, sociocultural environmental factors are likely to have an important influence on breastfeeding outcomes. Although exact pathways and mechanisms remain unclear, intervening at the environmental level has the potential to improve breastfeeding behaviour, as well as other health and reproductive outcomes.

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1. INTRODUCTION

The research in this thesis is presented in three papers with each covering different aspects of the link between environmental quality, socioeconomic status and breastfeeding in the UK. This thesis draws on literature from a range of disciplines, including demography, anthropology, evolutionary biology and public health. Adopting a human behavioural ecology approach, predictions are derived from the evolutionary framework of life history theory, within which breastfeeding is considered a key indicator of parental investment, and environmental quality and resource access are essential determinants of behaviour. In this introductory chapter I first explain the overall aims of the research, and then provide an overview of its motivations by highlighting the importance of both the outcome and predictors of interest.

1.1 AIMS AND OBJECTIVES

This thesis approaches the UK's infant feeding inequalities from an evolutionary perspective, exploring the potential role of environmental quality in explaining socioeconomic differentials in breastfeeding. Human environments are both social and physical, requiring consideration of a diverse range of environmental quality indicators in order to capture socioecological context sufficiently. In this thesis, I conduct secondary data analyses on two rich UK cohort datasets to explore how different aspects of the environment interplay with socioeconomic status to predict breastfeeding initiation and duration. The evolutionary framework of life history theory predicts that parental investment, like other aspects of reproductive behaviour, is patterned by environmental conditions and resource access. It is predicted that mothers will reduce breastfeeding, a key indicator of parental investment, in harsh environmental conditions and/or when resources are low, and increase investment when conditions are more favourable. In such a way, behavioural responses to environmental conditions can be viewed from an adaptationist perspective: different behavioural responses are not necessarily better or worse than one another, but instead reflect different solutions to different constraints and opportunities.

One aim of this research is therefore to shift intervention focus. Infant feeding is a contentious issue in the UK and whilst it is ultimately a mother's own decision whether or not she chooses to breastfeed, a focus on socioecological context helps to shift blame away from individuals. A human behavioural ecology perspective emphasises the links between people and their environments. We do not exist in a vacuum, instead our behaviour is shaped by multiple layers of influence. This thesis examines local environmental quality as one of these layers, in the hopes of showing the benefits of addressing environmental inequities.

A central question of this thesis is whether parental investment is responsive to environmental conditions in the high-income context of the UK. It is acknowledged that contemporary environmental conditions differ greatly from those in our ancestral past. And not only that, whilst it confers many advantages, breastfeeding is no longer essential for infant survival. Given this evolutionarily novel combination, to what extent are environmental quality and breastfeeding still linked?

As a move away from a reliance on aggregated data and proxy environmental measures in neighbourhood research, my thesis uses individualised and local measures of environmental experience. Whilst many studies rely on aggregated data as proxies for environmental condition, some studies have shown the importance of individual environmental perception for reproductive behaviours. The first paper of this thesis contrasts objective and subjective summary measures of environmental quality in their associations with breastfeeding. Whilst environmental quality and resource access are often conflated, I instead consider the two as distinct determinants of behaviour – different layers of influence – that exert their own, but also synergistic effects. Both are thought to influence the trade-offs women make. For this reason the first paper also explores whether environmental conditions and socioeconomic status interact with one another to predict breastfeeding outcomes.

The second paper of my thesis represents a shift in thinking in response to the findings of my first paper. Given the relatively weak effect of subjective environmental experience on breastfeeding outcomes, I sought out environmental indicators that were less to do with women's perception and more to do with subtle, less-perceivable elements. In addition, whilst in my first paper I wanted to capture environmental experience holistically by including all indicators in a factor analysis to produce summary scores of environmental quality, I realised that the inability to identify which specific aspects of the environment were driving the observed effects made it difficult to recommend particular avenues for intervention. As such, my second paper looks at environmental indicators separately, even down to different chemical compounds, in an attempt to understand mechanisms of effect as well as specific avenues for intervention.

Environmental quality is a neutral term, representing a quantification of environmental conditions, becoming only negative if prefixed with "low", and positive if prefixed with "high". My first paper considers the impact of improved environmental quality on breastfeeding chances, but my second paper focuses instead on the impact of increased exposure to environmental pollutants and worse household condition i.e. *decreased* environmental quality. The coding of variables shifted direction from Paper 1 to Paper 2. Odds ratios and hazard ratios therefore shift to comparing those with worse environmental experiences to those with better experiences, thereby focussing on relative disadvantage rather than relative advantage and helping to quantify the problem and highlight the issue better. This reflects a shift in my thinking towards focussing on vulnerable populations and aligns well with the aim of providing policy recommendations.

A final aim of my thesis is to test whether breastfeeding clusters with other demographic traits and parenting behaviours to form distinct "fast" or "slow" reproductive strategies consistent with life history theory predictions. The third paper therefore provided an opportunity to situate breastfeeding amongst other behaviours and to further test the extent to which both environmental conditions and resource access influence behaviour in a high-income context like the UK. In sum, this thesis has multiple objectives:

1) to investigate the role of environmental quality and subjective environmental experience in determining breastfeeding behaviour;
2) to measure environmental quality holistically with localised and individualised measures, disentangling its effects from those related to socioeconomic position (resource access);
3) to identify the specific aspects of the physical and sociocultural environment that are important for shaping the amount of investment provided through

breastfeeding, and that may therefore serve as potential avenues for intervention;

4) to test whether breastfeeding, as a form of parental investment, clusters with other parenting, reproductive, and health traits to form distinct life history strategies.

1.2 BREASTFEEDING IN EVOLUTIONARY CONTEXT

Reproduction is the most fundamental of evolutionary behaviours, yet human parents face especially complex trade-offs when deciding how many children to have and how much to invest in each of them (Shenk, 2011). Human Behavioural Ecology argues that people have been selected to respond flexibly to environmental conditions in ways that enhance their fitness and our cognitive and physiological machinery has adapted to enable us to assess the costs and benefits of adopting particular strategies (Mulder & Schacht, 2012). Life-history theory states that just like other animals, humans face two major energy allocation decisions, the first between growth and reproduction, and the second between the number of offspring produced and the amount to be invested in each (Mulder & Schacht, 2012).

Parents can invest in their offspring through a variety of ways, some social and others biological. In humans, paternal social investment is important in later years (Shenk & Scelza, 2012), but as with many other mammals (Hayssen & Orr, 2017), it is maternal biological investment that is considered vital during the early stages of an infant's life (R Sear & Mace, 2008).

As well as undergoing the energetically costly process of gestation, female mammals also endure the further biological cost of providing postnatal nourishment through the provision of milk (Dewey, 1997). As its namesake suggests, producing milk to nurse young is a defining feature of our phylogenetic class. Human breastfeeding when viewed in comparative evolutionary context, is our species' expression of a fundamentally mammalian trait, a trait whose expression is simultaneously dictated by evolutionary history and inherently flexible and responsive to infant growth and development patterns and environmental inputs (Hinde & Milligan, 2011; Tomori, Palmquist, & Quinn, 2017).

Mammalian genome sequencing studies suggest that milk secretory mechanisms evolved at least 160 million years ago; the mammalian predecessors Cynodontia and Mammaliaformes produced primitive 'milk' secreted by cutaneous glands before the divergence of the three extant Mammalia lineages (Capuco & Akers, 2009; McClellan, Miller, & Hartmann, 2008). Mammals in two of these lineages, Metatheria (marsupials, e.g. kangaroo and opossum) and Montremata (egg laying, e.g. platypus and echidnas), produce milk which varies considerably in composition during lactation, with simple milk during early lactation and nutrient-dense milk in later lactation. In contrast, the third lineage, Eutheria, produce milk which is complex throughout the entire process of lactation (Capuco & Akers, 2009). The Eutheria are a diverse clade of placental mammals including humans, cows, cats and rodents (to name a few) and for whom substantial foetal nourishment is placentally-sourced (Capuco & Akers, 2009).

Lactation strategies also vary within these mammalian lineages (Hayssen & Orr, 2017). Human breastfeeding is very different from bovine lactation for example: cows produce about five times more milk per day than humans; mature cows' milk has a higher fat and protein concentration but a lower lactose concentration than mature human milk; and the protective biological factors contained in milk also differ with IgG dominating the immunoglobulin profiles of cow's colostrum (at about 80%) whilst IgA is more abundant in human milk (at about 90%) (McClellan et al., 2008). These differences in yield and composition highlight that cow's milk is optimally designed, in an evolutionary sense, to meet the needs of a growing calf, not a growing human infant, and vice versa. In addition to differences in milk yield and composition, lactation strategies have three more interrelated dimensions: frequency and duration of nursing bouts, period of lactation until weaning, and number and sex ratio of infants reared simultaneously (Hinde & Milligan, 2011).

Even within the primate order there is great diversity (Hinde & Milligan, 2011). Compared to other primates, human milk synthesis stands out with its stable milk fat, sugar and protein concentrations throughout the first year coupled with declining milk volume by 9 months. This in in contrast to increasing milk fat and protein concentrations as infants age (e.g. Japanese macaques) and milk yield increasing during the first few months of lactation (e.g. baboons and Rhesus macaques) (Hinde & Milligan, 2011). In addition, compared to other primates who wean between 5 and 7.7 years, humans wean far earlier at an average of just 2.5 years (Kennedy, 2005) (and much earlier in many high income contexts (Victora et al., 2016)). This derived trait of early weaning supplemented with more nutritious adult foods is thought to have facilitated our unique levels of brain growth (Humphrey, 2010).

Whilst there is great variability and adaptability in lactation amongst mammals generally, and in infant feeding amongst humans specifically, breastfeeding has a clear evolutionary legacy and is the biological norm for our species. In this thesis, I explore variability in women's breastfeeding practices, in a context where formula feeding is the social norm (A. Brown, Raynor, & Lee, 2011; Lisa Dyson, Renfrew, Mcfadden, Herbert, & Thomas, 2005) and where women lack social and structural support for breastfeeding (Unicef UK Baby Friendly Initiative, 2016). Breastfeeding is often seen as an optional extra in public discourse rather than the starting point to which all other feeding methods should be compared (Hunt, 2016). Pervasive formula advertising contributes to low breastfeeding rates in the UK and the language used in medical and public health spheres talks of the "benefits" of breastmilk rather than the "costs" of formula, and this further exacerbates the issue (Hunt, 2016; Wiessinger, 1996). Whilst breastfeeding may not normally be essential for infant survival in high income contexts, there are clear morbidity differentials associated with infant feeding method (Ip et al., 2007; Alison Stuebe, 2009). There are also some population level mortality differences for particularly vulnerable infants such as those who are premature and fragile in these settings (Alison Stuebe, 2009; Victora et al., 2016).

1.3 BREASTFEEDING IN THE UK

1.3.1 In global context

The WHO now recommends exclusive breastfeeding until 6 months, followed by supplementation and continued breastfeeding up to 2 years or more (World Health Organization, 2015), yet many mothers across the globe do not reach these goals. Some mothers never initiate the process while others breastfeed infants for up to 3 or 4 years

(Faircloth, 2010). Still others opt for using alternatives such as wet nurses, cow's milk or formula (Wijndaele, Lakshman, Landsbaugh, Ong, & Ogilvie, 2009). Breastfeeding rates are lower in high-income countries than in low and middle-income countries, and breastfeeding prevalence at various infant ages decreases with increasing national wealth. Taking breastfeeding at 12 months as an example, prevalence is highest in sub-Saharan Africa, south Asia and Latin America (all 80%+) whilst in most high-income countries fewer than 40% of infants are still breastfed at this age (Victora et al., 2016). Norway is at 35% and the US at 27%. Sweden is at just 16% but the UK has particularly low rates, with <1% of infants given any breastmilk at 12 months. Rates of any breastfeeding at 6 months are also comparatively low in the UK, with just 34% of mothers still breastfeeding, compared to 49% in the US, 62% in Switzerland and 99% in Senegal (Public Health England, 2016; Public Health England & Unicef UK, 2016; Victora et al., 2016). The contrast between the US and UK breastfeeding rates is particularly stark given that the US is often similar or even worse than the UK when it comes to other health inequalities (Exworthy, Bindman, Davies, & Washington, 2006) and suffers from more structural barriers to breastfeeding. Breastfeeding holds a "paradoxical moral position" in both countries, with the health benefits (outlined in the next paragraph) promoted on the one hand, but the lived realities of breastfeeding conferring stigma and isolation on the other (Leeming, Williamson, Lyttle, & Johnson, 2013; Tomori, Palmquist, & Dowling, 2016). What's more, only 1% of UK women manage to exclusively breastfeed to the recommended 6 months and eight out of ten mothers stop breastfeeding before they want to (McAndrew et al., 2012).

The benefits of breastfeeding are well established and documented in the medical and public health literature. The positive impact of breastfeeding is felt three-fold (Spencer, 2008): with benefits reaped for infants (Chantry, Howard, & Auinger, 2006; Mårild, Hansson, Jodal, Odén, & Svedberg, 2007; Talayero & Lizán-García, 2006), mothers (Jordan, Siskind, & Green, 2010; AM Stuebe & Rich-Edwards, 2005; Tully & Ball, 2013) and society (Griffiths, Tate, Dezateux, & Millenium Cohort Study Child Health Group, 2005; Khoury, Moazzem, Jarjoura, Carothers, & Hinton, 2005, p. 65). Whilst the risks of not breastfeeding are greater in countries with greater burdens of infectious disease, there are still detrimental health impacts in high income countries (Victora et al., 2016). In terms of maternal health, breastfeeding is associated with a reduced risk of some female cancers (Collaborative Group on Hormonal Factors in Breast Cancer, 2002; Jordan et al., 2010) and a lowered risk of being overweight (Kac, Benicio, Velásquez-Meléndez, & Valente, 2004) and developing diabetes (AM Stuebe & Rich-Edwards, 2005). It is also associated with a reduction in stress and anxiety (Groër, 2005). The infant health benefits are numerous and include a reduced risk of developing respiratory diseases (Chantry et al., 2006), gastrointestinal conditions (Akobeng, Ramanan, Buchan, & Heller, 2006; Beaudry, Dufour, & Marcoux, 1995) as well as various infections (Chantry et al., 2006; Mårild et al., 2007; Quigley, Kelly, & Sacker, 2007; Talayero & Lizán-García, 2006). One of the ways in which society benefits is through the reduced expenditure on artificial feeding products and the associated reduction in environmental costs imposed by their manufacture and distribution (Gartner et al., 2005; Khoury et al., 2005; Radford, 2005). Breastfeeding also reduces work absenteeism as less time off is needed to care for sick infants and it therefore also benefits the economy (Gartner et al., 2005; Khoury et al., 2005). Lastly, breastfeeding can also lead to a reduction in NHS costs due to its protection against infant hospital admissions (M. S. Kramer, Chalmers, Hodnett, Vanilovich, & Mezen, 2001; Talayero & Lizán-García, 2006). Each year the cost to the NHS of treating just five illnesses related to babies not being breastfed (ear infection, chest infection, gut infection, necrotising enterocolitis and breast cancer) is a staggering £48 million (Renfrew et al., 2012).

1.3.2 History and within-UK variation

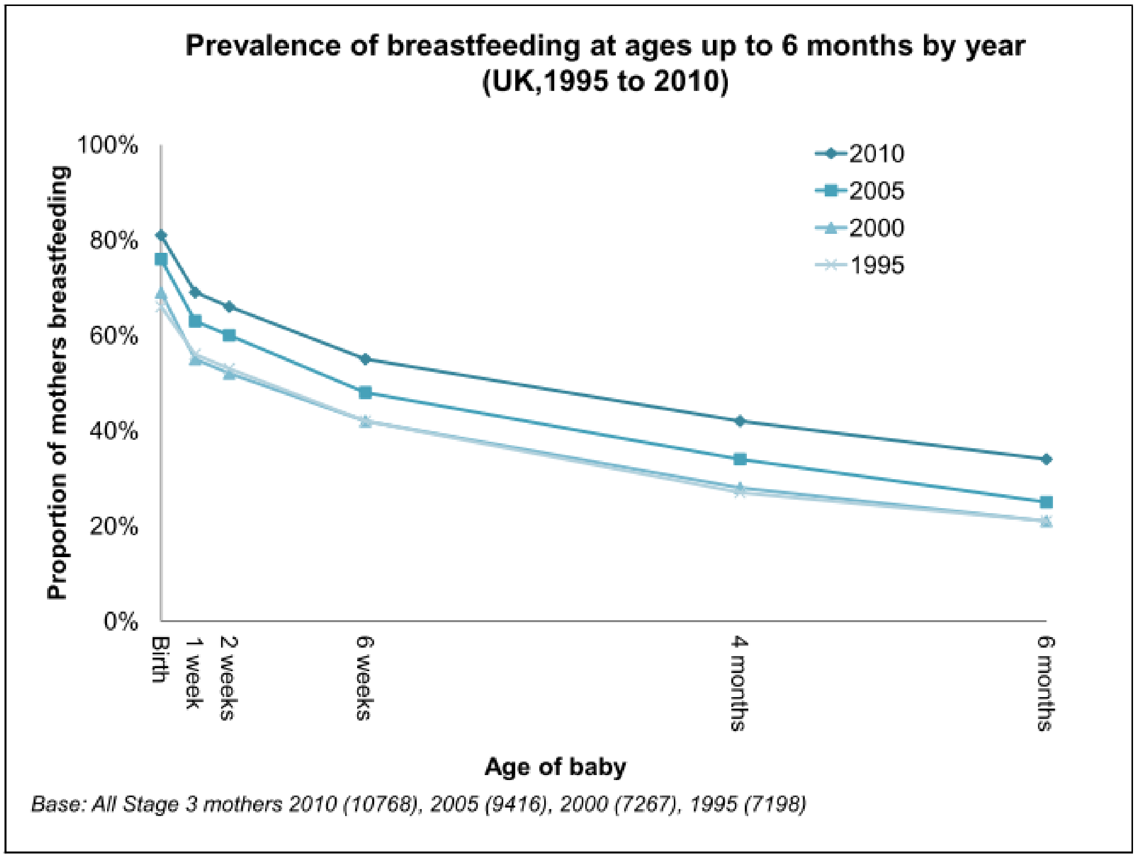
Breastfeeding is still rarely accepted as the norm in high-income contexts (Tohotoa, Maycock, & Hauck, 2009). Although Western countries have shown an upward trend in breastfeeding rates since the 1990s (van Rossem et al., 2009), formula is viewed as the normal way for mothers to feed their infants (A. E. Brown, Raynor, & Lee, 2011; McFadden & Toole, 2006; Tomori et al., 2016). UK Breastfeeding rates were relatively high at the start of the 20th century, particularly amongst the poor but after the First World War artificial feeding became more widespread as dried milk became more available and bottle feeding became more hygienic. The century's declining infant mortality rates and the scientific community's embrace of artificial feeding as just as good as breastfeeding paved the way for a steady decline in breastfeeding rates from the 1940s (Weaver, 2009). UK Breastfeeding rates were their lowest in the 1960s and

70s when formula milk was first promoted as a superior alternative to breastfeeding but have increased slowly over the last half a century (Bolling C.; Hamlyn A., K.; Grant, 2005; Crowther, Reynolds, & Tansey, 2007). The availability of safe breastmilk substitutes gives women in high-income countries like the UK considerable flexibility so that decisions about whether and for how long to breastfeed infants become complex, involving the consideration of many costs and benefits.

The national Infant Feeding Survey is a valuable source of breastfeeding data in the UK, having been conducted every five years from 1975 to 2010 (McAndrew et al., 2012). Findings from the 2010 survey showed England faring better than the rest of the UK, with initial breastfeeding rates reaching 83% while Wales reached 71%, Scotland 74% and Northern Ireland only 64%. Likewise, prevalence at six months was higher in England than in the other countries (36% versus 23% in Wales, 32% in Scotland and 16% in Northern Ireland) (McAndrew et al., 2012). All of the UK countries have however shown improvements over time. Political, cultural, gender and socioeconomic dynamics may drive differences in infant feeding patterns in the four countries and it is likely that variation occurs at smaller geographical scales too.

Considering the UK as a whole, breastfeeding initiation rates rose from 62% in 1990 to 76% in 2005, and further to 81% in 2010 (Cabieses, Waiblinger, Santorelli, & McEachan, 2014; McAndrew et al., 2012). Figure 1.1 illustrates the gradual increase in breastfeeding rates at different infant ages over time but also shows that improvements were only really made after 2000 onwards.

Figure 1.1: Prevalence of breastfeeding at ages up to 6 months for the four most recent UK Infant Feeding Surveys (1995 to 2010)



Sourced from McAndrew et al., 2010.

Unfortunately the national Infant Feeding Survey was decommissioned after 2010 (a great loss to the breastfeeding research community) and infant feeding statistics are instead now calculated from local provider data. Recent data suggests that breastfeeding rates are dropping slightly, although there is variation across the different UK countries. Data from NHS maternity service providers has shown that breastfeeding initiation rates have ranged from 71.7% to 74.6% over the last nine years in England (NHS England, 2017), whilst Public Health England's latest quarterly statistics put current rates of any breastfeeding at 6-8 weeks at 44.4% (Public Health England, 2018).

1.3.3 Policy arena

The UK government echoes the WHO's recommendations, with both the Department of Health and NHS recommending that babies are exclusively breastfed for the first 6 months, and that this is followed by the introduction of complementary solid foods alongside continued breastfeeding. The breastfeeding policies of the different UK countries vary slightly, but all draw on the strong evidence that the early years of life are important for infant health and relationship building. They all acknowledge the central role of breastfeeding within this and emphasise that mothers needs supportive environments in order to be able to breastfeed. More detail on current country-specific policies is outlined in brief below.

1.3.3.1 England

English national policy emphasises the importance of early years interventions for later life outcomes. Breastfeeding is seen as an important part of the picture, helping to improve infant and maternal health and foster good relationships. Emphasis is put on a whole systems approach to create "the right environment to promote and support breastfeeding" (Public Health England, 2016). NICE guidelines underline the crucial role of breastfeeding, and call for the Baby Friendly Initiative to be implemented as a minimum standard (NICE National Institute for Health and Care Excellence, 2008). The Department of Health and Public Health England task Local Authorities with prioritising breastfeeding support and increasing breastfeeding initiation and prevalence rates (Unicef UK, 2018a). Public Health England infant feeding services commissioning guidance stresses four steps that need to be taken: 1) raise awareness that breastfeeding matters, 2) provide effective professional support to mothers and their families, 3) ensure that mothers have access to support, encouragement and understanding in their community, and 4) restrict the promotion of formula milk and baby foods (Public Health England & Unicef UK, 2016).

1.3.3.2 Northern Ireland

The Department of Health Social Services and Public Safety for Northern Ireland (DHSSPS) produced two key strategy documents in 2012 – a draft breastfeeding consultation document *A Ten Year Breastfeeding Strategy for Northern Ireland* and a public health strategy consultation document *Fit and Well Changing Lives 2012-2022*. *Breastfeeding – A Great Start: A Strategy for Northern Ireland 2013-2023* was launched a year later and aims to improve maternal and infant health and well-being. As in England, emphasis is placed on creating supportive environments for breastfeeding mothers and children (DHSSPS Department of Health Social Services and Public Safety for Northern Ireland, 2013; Unicef UK, 2018b).

1.3.3.3 Scotland

Scotland's *Improving Maternal and Infant Nutrition: A Framework for Action* has helped to prioritise breastfeeding promotion and support, by placing the nutritional needs of pregnant women, babies and young children in the context of wider population health (The Scottish Goverment, 2011; Unicef UK, 2018c). Scotland has seen a recent rise in breastfeeding rates, likely due to its now widespread Baby Friendly accreditation status (Broadfoot & Britten, 2005).

1.3.3.4 Wales

Wales also emphasises the importance of services for children and their families in improving outcomes in early years and beyond. Their *Early Years Outcomes Framework* is paving the way for better data monitoring and service planning (Welsh Government, 2015). Welsh Health Boards are striving towards Baby Friendly Initiative accreditation and a 2014 review of the country's health programmes has identified the need for a system-based approach to promote and normalise breastfeeding (Unicef UK, 2018d).

1.3.4 Socioeconomic gradients in breastfeeding

Socioeconomic status (SES)[1] is a multifaceted construct, which in high-income contexts is usually indexed by income, education and/or job status and is measured at the individual, family or area-level. In evolutionary studies, SES has been conceptualised as representing parental condition (Wander & Mattison, 2013) or a marker of the resources a parent has available (Quinlan, Quinlan, & Flinn, 2005). Both of which are important influences on the trade-offs parents make regarding how best to invest their resources, including how much to invest in breastfeeding any given offspring. Breastfeeding is of course not the only outcome affected by SES. There is strong evidence of a

[1] I use the term 'socioeconomic status' in the first paper of my thesis, but shift to 'socioeconomic position' (SEP) in my second, and the last paper focuses instead on 'socioeconomic disadvantage'. This reflects a shift in my thinking, not dissimilar from my shift from measuring associations between breastfeeding and improved environmental quality to measuring instead associations between breastfeeding and increased exposure to worse environmental conditions. In both cases my focus realigns to think about who is most vulnerable, quantifying disadvantage rather than advantage.

socioeconomic gradient in many health outcomes, with inequities consistently found across the lifecourse (Weightman et al., 2012). There are disparities in both birth (Morello-Frosch & Shenassa, 2006; Weightman et al., 2012) and mortality outcomes (Davey Smith et al., 1998) but also in several other aspects of health. Unhealthy behaviours such as smoking, poor diet and low levels of physical activity tend to cluster disproportionately in lower socioeconomic groups (Buck & Forsini, 2012; Nettle, 2010b; Pampel, Krueger, & Denney, 2011). The fact that these social gradients in health behaviours have persisted over time is likely due to the equally persistent level of inequality in our society (Nettle, 2009, p. 937).

Socioeconomic differentials are well-established in breastfeeding behaviour (H. Kaplan, 1996) although the direction of association varies. Whereas in low and middle income countries low socioeconomic status is associated with increased breastfeeding rates (Davies-Adetugbo & Ojofeitimi, 1996), the reverse is true in high-income countries (Beale et al., 2006; Dubois & Girard, 2003; McAndrew et al., 2012). Although reducing socioeconomic differentials in breastfeeding has the potential to reduce health inequalities in the UK (McFadden & Toole, 2006, p. 157; Sacker, Kelly, Iacovou, Cable, & Bartley, 2013), the mechanisms through which socioeconomic status acts have not been thoroughly explored (Swanson, Power, Kaur, Carter, & Shepherd, 2006, p. 298). Although often measured using combinatory indices (e.g. the Index of multiple Deprivation (IMD) at the area-level), it is plausible that income, education and employment may enhance or constrain breastfeeding separately (Geyer, Hemström, Peter, & Vågerö, 2006; Heck, Braveman, Cubbin, Chávez, & Kiely, 2006). The most common ways of measuring socioeconomic status in breastfeeding research as well as some possible linking mechanism are outlined below.

1.3.4.1 Area-level socioeconomic status

Area-level measures of socioeconomic status are often used in public health research, including research into breastfeeding. Arguably the most commonly used indicator in England is the IMD, versions of which also exist for Scotland, Wales and Northern Ireland. Other area-level SES markers used in UK breastfeeding research include the Child Poverty Index (Bartington, Griffiths, Tate, & Dezateux, 2006) and council tax valuation bands (Beale et al., 2006). The IMD consists of several separate deprivation domains: income; employment; health and disability; education, skills and training; barriers to housing and services; crime; and living environment (McLennan, Barnes, Noble, Davies, & Garratt, 2011). UK studies present mixed results, with links to breastfeeding cessation found in some studies (A. E. Brown, Raynor, Benton, & Lee, 2010; Oakley, Henderson, Redshaw, & Quigley, 2014) but not in others (Agboado, Michel, Jackson, & Verma, 2010).

It is possible that women living in deprived neighbourhoods may experience additional stressors compared to people living in less deprived areas (Rollings, Wells, & Evans, 2015, p. 192). This extra stress may physiologically interfere with breastfeeding (Zhu, Hao, Jiang, Huang, & Tao, 2012) or emotionally make the process too much to deal with (Dozier, Nelson, & Brownell, 2012; Heinig et al., 2006). Poorer areas may also be more crowded and women may be more likely to feel embarrassed breastfeeding in public when there are more people around (H. J. Lee, Elo, McCollum, & Culhane, 2009, p. 1255).

1.3.4.2 Income

Higher incomes are generally associated with higher breastfeeding initiation and continuation rates (Awi & Alikor, 2006; A. E. Brown et al., 2010; Li, Darling, Maurice, Barker, & Grummer-Strawn, 2005). Breastfeeding is seen as a privilege of the wealthy; as one low-income mother from the US – where there is no statutory maternity leave for working women - put it "*it is easy for women to breastfeed if they are financially secure and don't have to work*" (Guttman & Zimmerman, 2000, p. 1467).

Not only can poorer women not afford to take the time off from work, they are unlikely to be able to afford the additional luxuries of paid-for support that wealthier women may use. Although there are free services offered through the NHS and children's centres (Condon & Ingram, 2011), if extra one-to-one help is needed, lactation consultants may be prohibitively expensive charging upwards of £60 per hour (see London Lactation Consultants, 2014 for an example). Bottle feeding of course incurs the additional cost of buying formula milk, which can work out to around £45 a month. However, this economic investment may seem less costly to low-income women than investing physiological and time resources in breastfeeding. In addition, the inability to afford a car and having to travel by public transport may mean that the common feelings of embarrassment when breastfeeding in public (Guttman & Zimmerman, 2000; Khoury et al., 2005) may be amplified for low-income women (McFadden & Toole, 2006, p. 163). Another possible way in which income affects breastfeeding is through economic strain and poverty-related stress (Diemer, Mistry, Wadsworth, López, & Reimers, 2013).

1.3.4.3 Education

Education is positively associated with breastfeeding outcomes but it is not clear how it improves breastfeeding initiation and duration. It could be that it enhances efficacy in seeking out breastfeeding information and support (Heck et al., 2006, p. 52). The benefits of breastfeeding may even be explicitly taught at higher education levels, dependent on the subject of study. Direct knowledge about breastfeeding and its benefits will likely come from other, less formal avenues of education (Heck et al., 2006, p. 52) such as antenatal classes (L Dyson, McCormick, & Renfrew, 2005), school-based promotion (Swanson et al., 2006) or through breastfeeding support sessions. It is conceivable that such avenues of information dispersal may be differentially available according to general education level but they may also exert their own independent effects on breastfeeding outcomes.

More highly educated women may hold antenatal classes and other sources of breastfeeding education in higher esteem than less educated women, which could further contribute to education differentials in successful breastfeeding. Less educated women tend to be more likely to fear that their infants will not get full on breastmilk alone (McFadden & Toole, 2006, p. 165; Petry, 2013, p. 16) – a concern which may be further exacerbated by other family members (Heinig et al., 2006). In fact, interventions which provide breastfeeding-focussed classes for fathers (Maycock et al., 2013; Susin & Giugliani, 2008) or grandmothers (Aubel, Touré, & Diagne, 2004; Meedya, Fahy, & Kable, 2010) have shown positive effects on breastfeeding outcomes, further demonstrating the importance of breastfeeding-specific education. Although maternal education has been hypothesised to have more of an influential role in determining breastfeeding behaviour (Heck et al., 2006), it may be worthwhile including both maternal and paternal measures when exploring educational relationships with breastfeeding (Heck et al., 2006; Kristiansen, Lande, Øverby, & Andersen, 2010) as both parents may be involved in seeking out breastfeeding information and support.

Leaving full-time education has been argued to be the best proxy measure for assessing socioeconomic status in health research (M Marmot, 2004) and this measure is often used in breastfeeding studies (Oakley, Henderson, et al., 2014). Another alternative is the highest qualification achieved (Auger, Park, Gamache, Pampalon, & Daniel, 2012). One issue with measuring qualification types is how to rank overseas qualifications, while years of education tells you little about the actual lesson content received.

1.3.4.4 Job status

Women in the UK in higher status occupations (such as managerial positions) are more likely to initiate breastfeeding than women in lower status occupations (such as routine occupations like shop or factory work) or who have never worked (Bishop, Cousins, Casson, & Moore, 2008; A. E. Brown et al., 2010; L Dyson et al., 2005, p. 3; McAndrew et al., 2012; Sloan, Sneddon, Stewart, & Iwaniec, 2006). Some low-status jobs may not permit enough breaks to give women adequate time to breastfeed or pump milk (Heinig et al., 2006). Lower SES women are also more likely to be employed in hazardous occupations, such as with toxic products in factory work, which can reduce their willingness to breastfeed due to concern over exposure affecting their milk (Heck et al., 2006, p. 52).

However, there are some employment situations – for women in both high and low status jobs - that may be conceived as creating barriers to maintaining breastfeeding (Andrew & Harvey, 2011). Working mothers may opt not to breastfeed for fear of negative consequences for their careers. Women in higher status jobs may have even higher opportunity costs in this regard (Huang & Yang, 2015, p. 55). This is however likely offset by higher status jobs being more likely to facilitate breastfeeding in the work place (Heck et al., 2006, p. 52) and usually involving more flexibility. For example, research has suggested that women in administrative and manual occupations are likely to give up breastfeeding quicker than women in other occupation types (Kimbro, 2006), which may be due to the relatively low levels of working flexibility these roles afford. Similarly, whether a mother is working part-time versus full-time will have an impact on her flexibility to accommodate breastfeeding (Heck et al., 2006, p. 52).

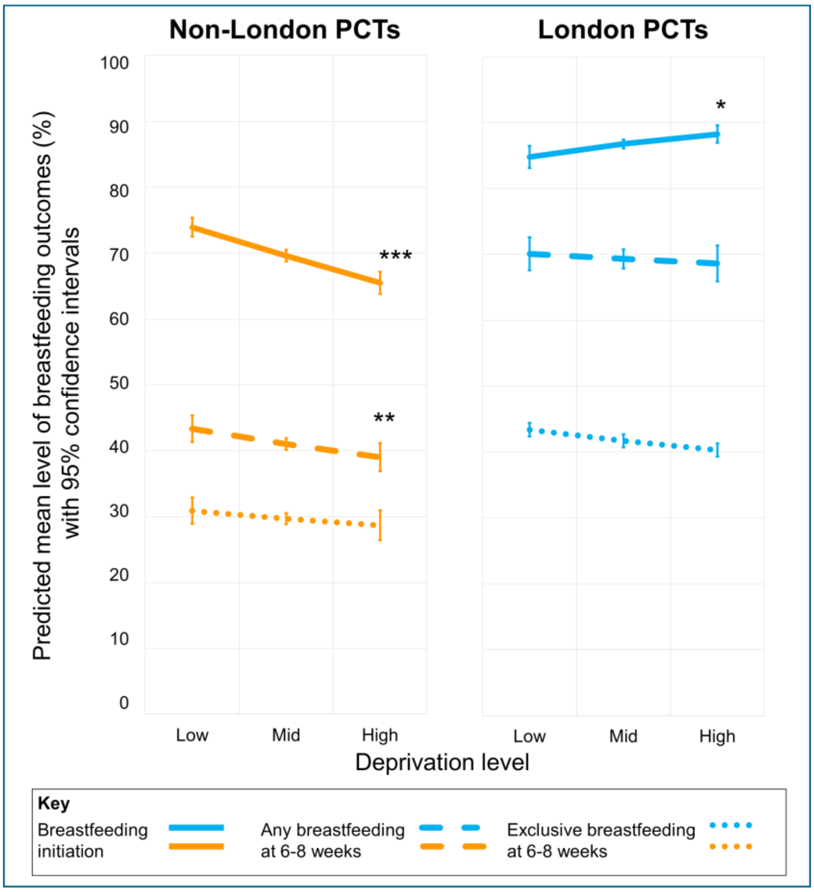
If breastfeeding is perceived as a barrier to returning to work (Arlotti & Cottrell, 1998; Guttman & Zimmerman, 2000, p. 1466; Huang & Yang, 2015, p. 46) or to getting a job in the first place, mothers who need the income more may forgo breastfeeding in favour of employment (Sloan et al., 2006). The provision of paid maternity leave is also important as is exemplified by loss of income being one of the main reasons women do not take family leave in the US (Huang & Yang, 2015, p. 46).

Occupational class based classification systems (Collis, 2009; Office for National Statistics, 2010) require asking several questions to correctly assign someone to the correct category (Office for National Statistics, 2010, p. 17). Like with income and education, whether maternal or paternal employment is measured is important, particularly as maternal employment has been shown to be negatively associated with breastfeeding while paternal employment shows the opposite relationship (Heck et al., 2006, p. 52). As many new mothers are unlikely to be currently working, it is useful to ask about most recent job to avoid unnecessary missing data in surveys.

1.3.4.5 Exceptions

There are cases when the predicted positive association between SES and breastfeeding doesn't hold. For example, a Dutch study found that although education seemed to be positively associated with breastfeeding initiation and continuation up until 2 months, the continuation of breastfeeding between 2 and 6 months did not differ between mothers in the highest and lowest education categories (van Rossem et al., 2009). Similarly, a UK study found that when SES was assigned according to council tax property valuation bands, there was no SES difference in how difficult breastfeeding was believed to be nor in how strongly women agreed that it restricted mothers' freedom (Beale et al., 2006).

Figure 1.2: Breastfeeding outcomes by deprivation level and Primary Care Trust (PCT) grouping for 2011/2012



*Models adjusted for ethnicity, education, age, smoking, and hospital maternity and reproductive health spend. *p≤0.05; **p≤0.01; ***p≤0.001.*

Area-level research has suggested that the SES-breastfeeding trend may be spatially patterned. One study found SES-breastfeeding associations only outside of London (Oakley, Renfrew, Kurinczuk, & Quigley, 2013), while my MSc research using Department of Health data at the Primary Care Trust level suggested that in 2011/12 London initiation rates were actually highest in the most deprived areas (Figure 1.2; for more detail see Appendix E.1 for a poster of this work).

1.3.5 Ethnic differences in breastfeeding

Socioeconomic status is not the only way that large societies are stratified. The UK is home to great diversity, with people of various ethnic backgrounds and immigration histories calling this country home (Office for National Statistics, 2012). The last UK Infant Feeding Survey found that mothers from Black (96%) and Asian (95%) ethnic backgrounds had the highest incidences of breastfeeding (McAndrew et al., 2012).

Ethnic differences are however dependent on context. Although both high-income westernised societies, the US and the UK differ markedly in their ethnicity-related breastfeeding patterns. For example, unlike in the UK, Black mothers have particularly low breastfeeding rates in the US (Y. J. Kelly, Watt, & Nazroo, 2006). In England, there seems to be a positive influence of ethnic diversity and mixing of cultures (Griffiths et al., 2005), suggesting that protective sociocultural norms and practices can diffuse across different ethnic groups to some extent.

Ethnicity and socioeconomic status can be intertwined, with some ethnic minorities also being socioeconomically disadvantaged. For example, ethnic minorities may be more likely to live in deprived areas of the UK than their White counterparts (McAndrew et al., 2012). Socioeconomic status and ethnicity do however impart different influences on breastfeeding, and socioeconomic status may have more of a beneficial effect in some ethnic groups than others. For example Kelly et al. found that higher income levels were associated with increased odds of initiating breastfeeding amongst White and Asian mothers, but that it had less of a consistent effect amongst Black mothers (2006).

1.4 CONCEPTUAL FRAMEWORK

Whilst it is clear that there are socioeconomic differentials in breastfeeding behaviour, research hasn't comprehensively answered *why* SES and breastfeeding are linked, and in particular, has not answered (or even asked) this question at an ultimate, evolutionary level. This section introduces evolutionary life history theory, the central framework for this thesis, and explains how breastfeeding is a key indicator of parental investment, and how it fits into this model of human behavioural ecology. In doing so I introduce the justification for my main hypothesis for my first two papers – that breastfeeding will be reduced in harsh environments. I also introduce the concept of life history strategies which is particularly relevant for the last research paper of the thesis.

1.4.1 Breastfeeding as a topic of interdisciplinary interest

Breastfeeding is a topic that has attracted research interests from a variety of disciplines. Evolutionary biology has shown us that like several other mammalian species, humans experience lactational anovulation where weaning age and interbirth interval (IBI) are closely related (Kachel, Premo, & Hublin, 2011). The suckling stimulus delays the resumption of sexual cycling and the time between conceptions is mediated by suckling frequency and duration (P. C. Lee, 1996, p. 88). The duration and frequency of breastfeeding will influence a woman's interbirth interval, which in turn has an effect on her fertility. Breastfeeding's relationship with interbirth intervals therefore also makes it a phenomenon of demographic interest. Demography has been interested in breastfeeding as a proximate determinant of fertility (Bongaarts, 1978). Evolutionary demographers have expanded on this by adopting a life history theory framework to study breastfeeding. Demographic change is also important to consider when analysing breastfeeding interventions as age structure and ethnic composition are likely to affect breastfeeding rates within specific areas over time (Griffiths et al., 2005).

Some sociological and anthropological work has emphasised the importance of the social environment, focussing on support from family and healthcare professionals (Condon & Ingram, 2011; Emmott & Mace, 2015; Leeming et al., 2013; Sherriff & Hall, 2011; Tohotoa et al., 2009), while other work has emphasised cultural barriers created by the sexualisation of the breast (Bailey, Pain, & Aarvold, 2004; Leeming et al., 2013; MacGregor & Hughes, 2010; McFadden & Toole, 2006), the pervasiveness of formula advertising (Gartner et al., 2005; Kean, 2014; MacKean & Spragins, 2012) or a modern day lack of embodied knowledge (Hewlett & Winn, 2014; P Hoddinott & Pill, 1999; Holman & Grimes, 2003; O'Campo, Faden, Gielen, & Wang, 1992; Wambach & Cole, 2000).

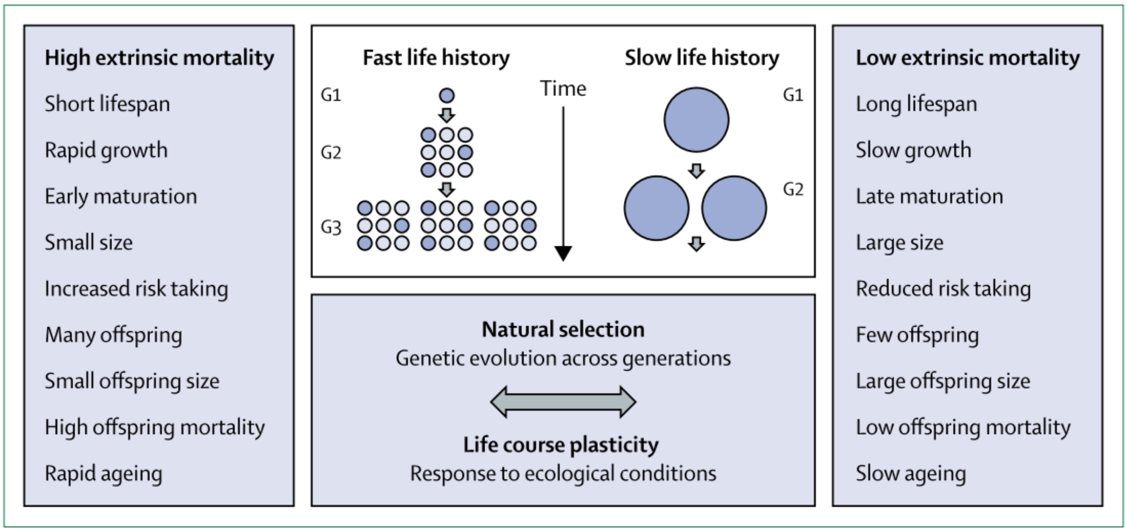
Evolutionary anthropological work has also shown us that like other primates, our infant feeding strategies are affected by our socioecological context (Hinde & Milligan, 2011; Kachel et al., 2011). Optimal allocation of resources across the lifespan depends on both socioecological and individual factors. Individual factors relate to a person's lifestyle or their genetic disposition, whereas socioecological factors refer to extrinsic factors including both physical and sociocultural elements.

Evolutionary ecology research grounded in life history theory has emphasised the importance of the physical environment in determining human behaviour, arguing that where environments are uncertain or risky, i.e. with unstable resources or relatively high levels of morbidity and mortality, adopting a "live fast, die young" strategy may be advantageous (Nettle, 2009). As the central framework for my PhD research, I outline life history theory in more detail below. Predictions derived from a life history framework are not necessarily counter to predictions made by non-evolutionary researchers, but rather they provide a different level of explanation (i.e. at the ultimate, rather than the proximate level).

1.4.2 Life history theory

Life history theory is a framework about how resource allocation is divided across the lifespan (Copping & Campbell, 2014; S. Stearns, 1989). This results in variation because natural selection favours allocating resources in a way which maximises fitness, but exactly how resources are allocated will depend on the environment. Both behaviour and physiology are plastic, responding to environmental cues throughout the life course. Figure 1.3 illustrates how life histories pattern according to environmental quality, here indexed as extrinsic mortality. Fast life histories are favoured in harsher environments, whereas slow life histories are favoured in environments with lower mortality risk (Wells, Nesse, Sear, Johnstone, & Stearns, 2017). Evolutionary perspectives of human behaviour therefore emphasise the importance of environmental context in shaping behaviour.

Figure 1.3: Life history contrasts across a fast–slow continuum



Sourced from Wells et al., 2017. The size of the circles is proportional to adult body size, and filled circles indicate individuals that survive to reproduce. G1=first generation. G2=second generation. G3=third generation.

Life course plasticity means that mothers are adapted to exercise choice in breastfeeding practices (McDade & Worthman, 1998; Sellen, 2007). This “choice” is contingent on the local environment within which infant feeding decisions are made (McDade & Worthman, 1998). The costs and benefits of lactation are traded-off differently depending on context in order to maximise reproductive success and, as such, there is adaptive value in the variability in human lactation strategies (Núñez-de la Mora, 2014; Wander & Mattison, 2013). Evolutionary anthropologists working within the life history framework consider breastfeeding as a key component of parental investment behaviour, as is discussed in more detail in the section that follows.

1.4.3 Breastfeeding as parental investment

Breastfeeding is a critical aspect of parental investment as it is an energetically costly process, requiring twice as much daily energy as gestation (McDade & Worthman, 1998). Breastfeeding is additionally often time consuming and can prevent mothers from engaging in other activities (Pat Hoddinott, Craig, Britten, & McInnes, 2012; McDade & Worthman, 1998). Like other depreciable forms of parental investment then, breastfeeding is costly and necessarily affects the amount of resources available for women to invest in their own growth or future reproduction, or caring for other current offspring and assisting other kin (Quinlan, Quinlan, & Flinn, 2003). As such women are expected to make trade-offs regarding the level of investment to provide through lactation (Tracer, 2009) and the resources devoted to nursing can be viewed as an indicator of a mother’s desire and ability to invest in any one child (Quinlan et al., 2003). Shortened breastfeeding may for example reflect a decreased investment in the current offspring in favour of being able to reproduce again soon (Lienard, 2011; Nettle, 2009). To be clear, trade-offs in this sense do not refer to deliberate, voluntary, or conscious calculations of fitness costs and benefits of behaviours (Schlomer, Del Giudice, & Ellis, 2011, p. 498), but rather to sets of conditional developmental switches (Brumbach, Figueredo, & Ellis, 2009). It is also important to note that increased parental investment through breastfeeding is just one of several ways in which parents can enhance their reproduction and economic production (Quinlan et al., 2003), and as such it may be at least partially determined by the level of other types of parental investment provided.

1.4.3.1 Breastfeeding measures as indicators of parental investment

Initiation can be measured as ever having given a baby breastmilk, ever having tried to breastfeed (even with no milk transfer), or initiating within a specified time period. Early initiation refers to receiving breastmilk within the first hour (or sometimes first 24 hours) and is important in terms of health because it ensures that infants receive the colostrum which is rich in immunological properties and therefore important for decreasing the risk of neonatal mortality (Debes, Kohli, Walker, Edmond, & Mullany, 2013). In addition to its beneficial immunological properties, a recent expansion of interest in the microbiome has shown that breastmilk also harbours many bacteria (Clarke, O'Mahony, Dinan, & Cryan, 2014) which help to colonise the infant's gut and prepare it for its local ecology (Funkhouser & Bordenstein, 2013). From a parental investment viewpoint then, by initiating breastfeeding mothers are signalling that their infants are worth allocating resources to. In the cases where women have tried to breastfeed but the infant has had problems such as tongue-tie or an inability to latch (Edmunds, Fulbrook, & Miles, 2013), the mother has shown a willingness to invest despite the infant not being able to capitalise on that investment.

As early initiation is particularly beneficial for infant health, this could be considered an indicator of a particularly high level of investment. However, it could be that initiation may capture parental investment poorly due to it being so tied into hospital factors (particularly with the spread of the Baby-Friendly Hospital Initiative (Philipp & Radford, 2006) and the advice and support received by healthcare professionals (Ayton, Hansen, Quinn, & Nelson, 2012; Broadfoot & Britten, 2005; A. E. Brown et al., 2011; Hawkins, Stern, Baum, & Gillman, 2014). Whether breastfeeding is maintained after leaving hospital may therefore be a more suitable indicator of parental investment.

In light of the current WHO recommendations (World Health Organization, 2015), several papers have attempted to measure adherence to the key milestones of 6 months of exclusive breastfeeding and continued breastfeeding up until 2 years. These are most easily measured by questions pertaining to age at when the child was first introduced to other liquids or solids and the age he/she was last fed breast milk. Measuring exclusive breastfeeding is important from a health point of view as it has additional advantages over partial breastfeeding in terms of infection-related mortality and morbidity (Bai, Middlestadt, Peng, & Fly, 2009; M. S. Kramer & Kakuma, 2002). Mixed feeding is increasing in popularity, with mothers weighing up the pros and cons of breastfeeding and bottle feeding and compromising by combining the two (Cabieses et al., 2014; Kean, 2014; J. P. Smith & Forrester, 2013; A. M. Stuebe & Bonuck, 2011). From an evolutionary point of view, exclusive breastfeeding can be seen as a marker of increased parental investment as it will necessarily involve higher physiological and time costs than mixed-feeding (J. P. Smith & Forrester, 2013).

Defining weaning age is difficult as weaning does not relate to one particular moment in time but rather refers to an ongoing process (Hinde & Milligan, 2011) and is variably defined as when an infant's diet starts including solids or when breastfeeding has stopped completely (Quinlan, 2007). Longitudinal studies usually get around this issue by measuring whether the infant is still receiving breast milk at various time points such as at 6 weeks or at 6 months for example, rather than asking about a specific age at weaning. In terms of parental investment, duration of breastfeeding is a good way of quantifying the amount of investment received, with the assumption that a woman who breastfeeds for 6 months has provided more investment than a woman who stopped at 6 weeks.

Generally women who view breastfeeding more positively will report intending to breastfeed for longer than those who foresee more issues. Likewise those who have stronger breastfeeding intentions are also more likely to achieve their breastfeeding goals and tend to surpass those who care less (Cabieses et al., 2014; A. M. Stuebe & Bonuck, 2011). Women usually make their mind up about their chosen infant feeding method early on in pregnancy (Bailey et al., 2004). Infant feeding intentions may therefore also index parental investment, in that they may capture a willingness to breastfeed even if later constraints mean that mothers are unable to do so.

It is plausible that breastfeeding may not be a very straightforward predictor of parental investment, especially in high-income contexts, because mothers have to feed their babies somehow – either by breast or bottle-feeding, so that not breastfeeding doesn't mean that mothers are not investing at all in their children; just that they are investing differently in their children. By buying formula milk they are investing economically rather than investing their own energetic reserves in feeding their babies. It isn't clear how women weigh up the relative costs of investing energetically or economically in feeding their children. Deciphering this trade-off may be especially complex for well-nourished women where gaining sufficient calories to breastfeed is not a significant problem. Having said that, our behaviour may be shaped by mechanisms which evolved in the past, when breastfeeding was still a physiologically costly form of parental investment. If this is the case then mothers might still make investment decisions as if breastfeeding were still very costly.

1.4.4 Life history strategies

Within evolutionary biology, life history theory has been used to explain cross-species differences in allocation strategies regarding reproduction, maturation, and survival (S. C. Stearns, 1983). Natural selection favours individuals that schedule development and activities, i.e. allocate energy and resources, in a manner that optimises trade-offs over the life course and across varying ecological conditions. As an illustrative example, diagrammatic explanations of one such trade-off, that between survival and fecundity, are given in Figure 1.4 (adapted from Fabian & Flatt, 2012). Life history strategies are therefore adaptive solutions to a number of simultaneous fitness trade-offs. In cross-mammalian research, the fast-slow continuum manifests as large mammals with delayed maturation and long lifespans, long gestation periods and fewer offspring at one extreme and small mammals, with early maturation, short lifespans, short gestations and large litter sizes at the other (Bielby et al., 2007). Human behavioural scientists have recently begun to further conceptualise such strategies as a within-species individual characteristic.

Figure 1.4: Life history trade-offs

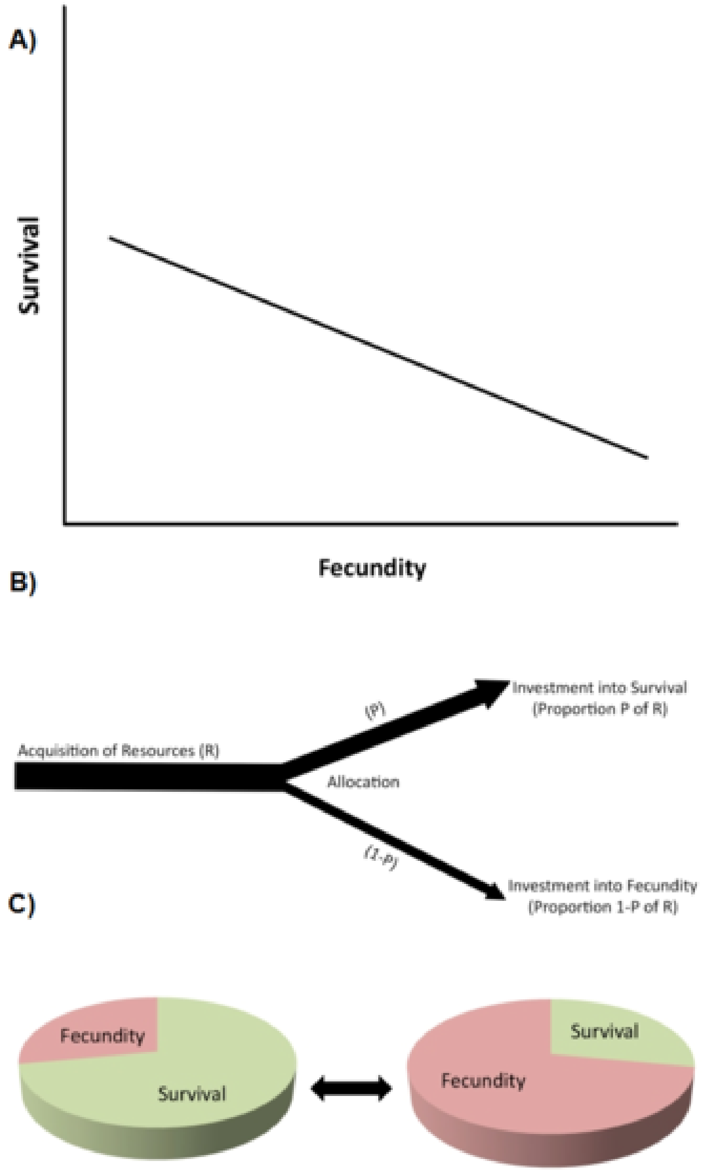


Image sourced and caption adapted from Fabian & Flatt, 2012.

Top (A): A trade-off between reproduction (e.g. number of children) and adult survival, one of the most commonly found negative relationships between life history traits.

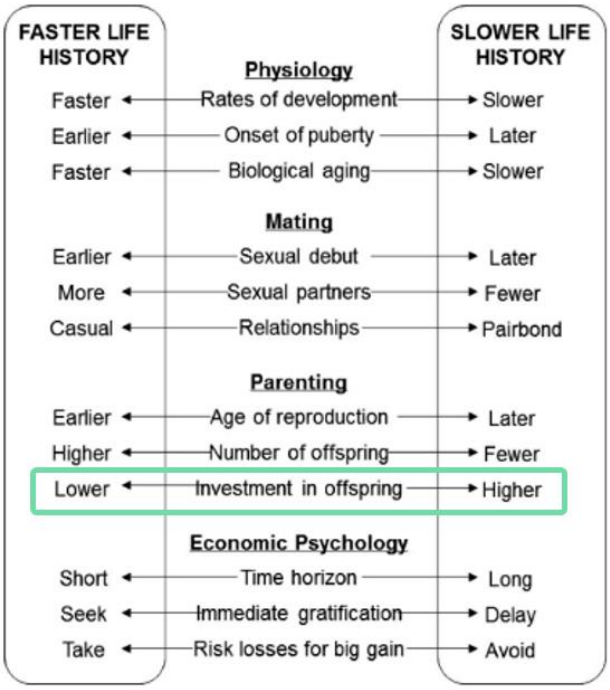
Middle (B): The so-called Y-model of resource allocation trade-offs. In this example, a limited resource (e.g. food) is acquired and differentially (competitively) allocated (invested) into physiological processes that affect survival at the expense of investment into reproductive functions (e.g. egg production, fecundity).

Bottom (C): A useful way of thinking about resource allocation trade-offs is to imagine the life history as being a finite pie.

It is assumed that over time, an individual's development, physiology, and behaviour are organised in a coordinated manner forming a "constellation of traits" (Cabeza de Baca & Ellis, 2017), but how cohesive are these strategies? How "organised" is the "constellation"? Are life history strategies in humans easy to identify and predict? Evolutionary life history theory provides an important framework for analysis both within and across species, and suggests that developmental patterns that arise from different trade-offs vary on a slow–fast continuum at both levels, but the theory is sometimes used too simplistically, dichotomising individuals as either fast or slow, rather than considering flexibilities in strategies over time or the existence of middling groups.

The clustering of reproductive behaviours such as early age at first birth and number of children may be adaptive responses to ecological conditions (Nettle, 2009). It is worth noting however, that although the empirical evidence does so far support a harsh-environment to fast life history prediction, the theoretical underpinnings for this link are not completely clear (Baldini, 2015). Different behavioural and physiological traits are however thought to pattern in a coordinated manner, so that "strategies" emerge. Whilst these strategies are not necessarily conscious, it is predicted that environmental conditions calibrate a coordinated suite of traits. This is illustrated in Figure 1.5.

Figure 1.5: Faster versus slower life history strategies



Adapted from Ellis et al., 2012. This list is indicative not exhaustive. Rectangle added to highlight where breastfeeding fits in this representation.

Breastfeeding would fall under the parenting domain in Ellis et al.'s diagrammatic representation above, and more specifically under investment in offspring. There is however some debate as to whether parental investment can be considered part of a life history strategy, as the most secure evidence about fast strategies is about the timing of first birth. One way to test whether parental investment does actually form part of a life history strategy would be to see whether infant feeding behaviours thought to represent faster strategies (i.e. reduced parental investment indicated by not breastfeeding or breastfeeding for only a short amount of time) cluster together with other indicators of fast life history theory such as younger age at first birth and higher fertility. This is something that I test in the last paper of my thesis (see Chapter Four).

The four domains in Figure 1.5 – physiology, mating, parenting, and economic psychology – are not exhaustive, and in fact, different researchers use both different terminology and different groupings. For example, sometimes health behaviours are also included as indicators of investment in self (somatic investment). Within the field of Evolutionary Psychology, there has been a further extrapolation of these strategies to include psychometric indicators and personality traits. These even go beyond the economically-oriented aspects included in Figure 1.5 and include personality traits such as dominance and hostility, as well as aspects such as religiosity and altruism (Hengartner, 2017; Richardson et al., 2017). There is contention regarding 1) which aspects of physiology and behaviour can be considered indicators of life history strategies and 2) whether psychometric measures are as valid as biometric measures. My third research paper addresses the first point, whilst I provide some discussion regarding the latter point below.

1.4.4.1 Critique of evolutionary psychology approach

In this thesis I take a human behavioural ecological approach. This involves examining actual physiological and behavioural outcomes, in contrast to the evolutionary psychology approach (Nettle, Gibson, Lawson, & Sear, 2013; Winterhalder & Smith, 2000). Researchers in the field of evolutionary psychology have asserted that personality assessment batteries can be used to successfully assign life history strategy. Evolutionary psychologists focus largely on mating behaviours and split people into short- and long-term mating strategists. More nuanced approaches acknowledge that women (and probably men) are likely to adopt a mixed strategy, favouring short- or long-term mating in different situations (Smiler, 2011). Another issue with these batteries is that they are predominantly based on data from university samples (Copping, Campbell, & Muncer, 2014). Not only is mating already decoupled from reproductive outcomes in contexts with widespread access to contraceptives, for many undergraduates (normally aged 18-21) a focus on mating either captures completely hypothetical behaviour or will reflect a time in their life when their behaviour is likely to be distinctly different from other times in their lives (i.e. more relaxed and promiscuous). Rarely are such scales tested on non-university samples.

Psychometric approaches capture personality and lifestyle rather than biological events; whilst they may be related to fast or slow strategies they can't be used as proxies for them (Copping et al., 2014). Batteries also blend individual behaviours with norms – what are they actually measuring? Socially preferred behaviour or actual behaviour? Biometric indicators capture what's actually happened rather than hypothetical situations. Psychometric indicators could capture plausible behavioural pathways through which biometric outcomes are realised, i.e. by acting as mediators (Figueredo et al., 2014), but their validity has not been robustly assessed and should be validated against more objective, definitive biometric indicators (Copping et al., 2014). My research focuses on actual mothers rather than just undergraduates, and on biometric and behavioural outcomes rather than just on personality and lifestyle. The majority of the traits used in my third paper are definitive - a mating strategy can change, but age at menarche and age at first birth can't. I capture the main metric of reproductive success – actual reproductive events – and focus on behaviours that have actually happened rather than what if scenarios.

Whilst the extrapolation to personality traits may be one step too far, there is evidence to suggest that life history traits cluster across different domains to some extent. Most studies focus on just one allocation domain e.g. reproductive or somatic effort, but a comprehensive strategy would imply clusters across different domains, reflecting functional suites of multiple traits aiming toward short term returns in harsh conditions and long term returns when environmental quality is better.

Some life history assessment batteries also blend together elements of current and past environments, relationships with parents and offspring, personality and lifestyle. Such blending obscures important inter-relationships (Copping et al., 2014) but also conflates two distinct aspects of life history theory. Life history strategies represent an individual's developmental response to the environment in which they inhabit. It is expected that reproductive strategies are conditional on environmental experience, and that women will adopt alternative strategies in order to maximise their reproductive success. Of course this has the caveat that in modern low fertility settings fertility behaviour is probably not fitness maximising (Stulp, Sear, & Barrett, 2016), though that doesn't mean it can't be studied from an adaptationist perspective. One strategy is not better or worse than another, rather strategies are alternative and conditional on environmental factors and thus serve to maximise reproductive success in different contexts (Belsky, 2012).

My third paper improves on existing human life history studies in several ways: 1) the study focuses on *actual* mothers rather than the *potential* mothers who comprise the majority of undergraduate samples; 2) I use definitive biometric and behavioural outcomes rather than just personality and lifestyle traits; 3) I capture the main metric of reproductive success – actual reproductive events – and focus on behaviours that have actually happened rather than what if scenarios; 4) I include several different domains of behaviour.

1.4.4.2 Environmental influences throughout the life course

It may not be fruitful to completely calibrate reproductive strategy based on outdated information; environmental conditions in adulthood, not just childhood, are likely to exert influences on reproductive and parenting behaviour (Coall, Tickner, McAllister, & Sheppard, 2016; Ellis, 2004; Kubinski, Chopik, & Grimm, 2017). This idea of plasticity contrasts with notions of sensitive or critical periods of exposure in epidemiology (Berens, Jensen, Nelson Iii, & Nelson, 2017; Cable, 2014; Srám, Binková, Dejmek, & Bobak, 2005) and instead suggests that life history strategy may be responsive to new environmental information throughout the lifespan. This is a central assumption of my research as I focus on how women's contemporary environmental exposure impacts infant feeding behaviour in my first two papers. Some life history events will predate contemporary socioeconomic/environmental conditions and as such it is useful to look at both childhood and adulthood conditions where possible. In my last paper where my focus on both outcomes and predictors broadens out, I also look at childhood environmental indicators. The role of the environment in shaping human physiology and behaviour is not a peculiar interest of evolutionary approaches, and environmental research has foundations in other disciplines too. The next section briefly introduces how other public health research has thought about environmental quality before setting out why a focus on the environment is important from a policy perspective.

1.5 ENVIRONMENTAL QUALITY

Environmental quality is often conflated with socioeconomic status in definitions of environmental harshness. Where the two are delineated, environmental quality is most usefully thought of as extrinsic risks to mortality and morbidity, whilst socioeconomic status is best thought of in terms of resource access/scarcity. Extrinsic risks to mortality-morbidity are independent from intrinsic survival efforts and traditionally take the form of predatory risk, famine, disease, or conspecific violence (Chang & Lu, 2016) but may incorporate any plausible threat to health and survival. Where environmental harshness refers to absolute levels of extrinsic risk, environmental uncertainty instead captures the random fluctuations in morbidity and mortality risks over time. Uncertainty can be further delineated into unpredictability and uncontrollability, with the latter referring to an inability to influence events and the former including events that are unavoidable and not pre-empted. The central premise of these various definitions is that under harsh environmental conditions, individuals face an increased risk of dying before reproductive age (or of becoming too ill to reproduce), which makes it “bio-logical” for them to develop faster, mature earlier and have children sooner rather than later (Belsky, 2012). Environmental quality is therefore a general and umbrella term, although I break it down in different ways in my research papers: Paper 1) objective versus subjective (each comprised of physical and sociocultural aspects); Paper 2) physical (and less-perceivable, or consciously processed); and Paper 3) adult versus childhood (including physical and sociocultural aspects).

Public health research began to explore environmental effects in an attempt to understand social inequalities (Diez Roux, 2007) and many aspects of health have been consistently shown to relate to neighbourhood level deprivation across multiple studies and datasets (Pickett & Pearl, 2001). Examples range from chronic diseases (Diez Roux, 2007) and the aging process (Park, Verhoeven, Cuijpers, Reynolds III, & Penninx, 2015), to health behaviours (Pepper & Nettle, 2014b), mental health outcomes (Galea et al., 2007) and social well-being (Robinette, Charles, Mogle, & Almeida, 2013).

Although there has been a tendency in some health research to conflate physical and sociocultural aspects (Rollings et al., 2015), there are evolutionary studies which make this distinction clear - for example by measuring both the positive effects of social support and cohesion and the negative effects of environmental hazards (Johns, 2011). Area-level processes can also be divided into material deprivation and social deprivation, whereby material aspects are linked to poverty and poor living conditions and social aspects refer more to isolation or a lack of social cohesion (Auger et al., 2012). It is thought that poor communities may experience a “double jeopardy” where socioeconomic stressors could interplay with environmental hazards to have negative impacts on health (Morello-Frosch & Shenassa, 2006).

The environment can be modified to improve health outcomes with less onus or pressure put on the individual (Nettle, 2009) and is therefore a useful avenue for intervention in breastfeeding. There is a historical tradition of placing blame on the individual when he/she becomes sick and the medicalisation of breastfeeding (Faircloth, 2010) has exacerbated feelings of pressure and guilt for new mothers (Earle, 2002; Fox, McMullen, & Newburn, 2015; Hauck & Irurita, 2003). Breastfeeding is a particularly emotive process with women's sense of self-worth and value intrinsically linked to its success (Hufton & Raven, 2014; Thomson, Ebisch-Burton, & Flacking, 2014), and as such a shift from the individual towards the environment in infant feeding discourse and indeed interventions would be helpful in improving emotional wellbeing of mothers and in turn the health of their children. Furthermore, by focusing on differences in environmental quality we can draw attention towards core economic inequities and concentrate on the benefits to be yielded through structural change (Nettle, 2010b, p. 5).

1.5.1 Environmental perception

Life history theory studies have shown that individual environmental perception has an important influence on reproductive behaviours (Johns, 2011; Johns, Dickins, & Clegg, 2011). For example, women are more likely to have lower birth weight babies (Auger et al., 2008; Nettle, 2010a) and to start reproducing at younger ages (Johns, 2011; Nettle, 2010a) when they rate their environments unfavourably. My research expands on this body of life history theory informed work by testing whether breastfeeding, as another component of reproductive behaviour and a marker of parental investment, also varies in accordance with subjective environmental experience. One study examined breastfeeding duration with other life history variables and showed it to be positively associated with neighbourhood quality, with women in the most deprived neighbourhoods breastfeeding their infants for almost 3 months less than those living in better-off areas (Nettle, 2010a, p. 391). However how socioeconomic deprivation at the area level is perceived by individuals, and how this in turn translates into breastfeeding decisions and practices has not yet been established.

1.5.2 Socioeconomic status and environmental quality

The role of individual condition in shaping behavioural repertoires also has to be taken in to account. Access to resources is key in patterning behaviour in several domains and in the same environmental context, healthier women are likely to have improved reproductive success (H. S. Kaplan & Lancaster, 2003). I consider socioeconomic position as a proxy for individual condition, and assume that the greater resources higher socioeconomic position brings allows for greater investment in any one domain. To borrow Reznick et al's analogy, greater resources provide a bigger pie to split into allocation slices (see Figure 1.4c), so those with higher socioeconomic position have better condition and can therefore invest *absolutely* more across multiple domains (both the pie and the slices are bigger), even if *relatively* they have to split across domains just like more disadvantaged individuals (they can still only cut so many slices) (2000). An individual's resources is not the same as their environmental condition; whilst the two are likely interrelated, they refer to separate axes of variation. In this way it can be seen how both SES and environmental quality shape life history trade-offs, in complementary but distinct ways. One of the findings of my thesis is that SES and environmental quality appear to be measuring different aspects of constraints and opportunities, and that the effect of one is not completely explained away by the other. I return to the implications of this in my discussion section.

1.5.3 Evolutionary theory meets policy

By applying evolutionary thinking to the social sciences we acknowledge that the environment plays an important role in shaping human physiology and behaviour, as it does for other animals (Nettle, 2009). Socioecological effects on health behaviours such as breastfeeding are important to evolutionary researchers as we conceptualise environments in terms of how harsh/stressful they are and in terms of resource availability to consider the consequent constraints and trade-offs imposed on behavioural strategies. Policy makers are also interested in environmental factors because it may be easier to intervene at the neighbourhood level than it is to just tell individuals to breastfeed. Evolutionary theory not only adds value by informing predictions, but the findings are also important for policy makers as they highlight aspects that policy makers can actually change.

1.6 CHOSEN DATASETS

Access to accurate data is critical for effective policy making, and many organisations are calling on the government to reinstate the five-yearly Infant Feeding Survey (Lactation Consultants of Great Britain, 2015; The British Dietetic Association, 2018). The Infant Feeding Survey not only provided insight into the number of women who breastfed to various milestones, but more importantly it also provided breakdowns by SES, maternal age, ethnicity, parity, previous breastfeeding experience, and timing of when mothers returned to work (Bolling C.; Hamlyn A., K.; Grant, 2005; McAndrew et al., 2012). This information is incredibly useful when it comes to allocating resources and tailoring interventions. Without this key data resource, breastfeeding researchers have had to look elsewhere to quantify the UK's breastfeeding problem. Whilst breastfeeding initiation and early stage prevalence data are available through health systems reporting mechanisms, reporting descriptive rates is not enough if we want to understand what is driving the variation in breastfeeding we see in the UK. This is where the UK's rich cohort datasets are valuable. With a whole range of information about different aspects of people's lives collected through regular surveys, these datasets enable researchers from a wide range of disciplinary focuses to test a wealth of different hypotheses.

Although chronologically the datasets I use in my thesis fall behind the last Infant Feeding Survey, the additional information they provide makes them better sources of data for my research questions. Both of the datasets used in this thesis have rich environmental quality, socioeconomic status and breastfeeding data. My three research papers each provide further background information on my chosen datasets, and further detail is provided in the respective cohort profiles (MCS: Connelly & Platt, 2014; BiB: Wright et al., 2013).

2. LOCAL ENVIRONMENTAL QUALITY POSITIVELY PREDICTS BREASTFEEDING IN THE UK'S MILLENNIUM COHORT STUDY (STUDY 1)

RESEARCH PAPER COVER SHEET

PLEASE NOTE THAT A COVER SHEET MUST BE COMPLETED <u>FOR EACH</u> RESEARCH PAPER INCLUDED IN A THESIS.

<u>SECTION A – Student Details</u>

Student	Laura J Brown
Principal Supervisor	Rebecca Sear
Thesis Title	Understanding socioeconomic disparities in breastfeeding in the UK: Exploring the role of environmental quality

<u>If the Research Paper has previously been published please complete Section B, if not please move to Section C</u>

<u>SECTION B – Paper already published</u>

Where was the work published?	**Evolution, Medicine & Public Health**		
When was the work published?	**August 2017**		
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For multi-authored work, give full details of your role in the research included in the paper and in the preparation of the paper. (Attach a further sheet if necessary)	I was responsible for the research design, and conducted the statistical analysis. I was also primarily responsible for writing this work. My supervisor supported this work in an advisory capacity and helped to edit the writing.

Student Signature: [redacted] **Date:** 26/11/2018

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ORIGINAL RESEARCH ARTICLE

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EVOLUTION, MEDICINE, & PUBLIC HEALTH

Local environmental quality positively predicts breastfeeding in the UK's Millennium Cohort Study

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ABSTRACT

Background and Objectives: Breastfeeding is an important form of parental investment with clear health benefits. Despite this, rates remain low in the UK; understanding variation can therefore help improve interventions. Life history theory suggests that environmental quality may pattern maternal investment, including breastfeeding. We analyse a nationally representative dataset to test two predictions: (i) higher local environmental quality predicts higher likelihood of breastfeeding initiation and longer duration; (ii) higher socioeconomic status (SES) provides a buffer against the adverse influences of low local environmental quality.

Methodology: We ran factor analysis on a wide range of local-level environmental variables. Two summary measures of local environmental quality were generated by this analysis—one 'objective' (based on an independent assessor's neighbourhood scores) and one 'subjective' (based on respondent's scores). We used mixed-effects regression techniques to test our hypotheses.

Results: Higher objective, but not subjective, local environmental quality predicts higher likelihood of starting and maintaining breastfeeding over and above individual SES and area-level measures of environmental quality. Higher individual SES is protective, with women from high-income households having relatively high breastfeeding initiation rates and those with high status jobs being more likely to maintain breastfeeding, even in poor environmental conditions.

Conclusions and Implications: Environmental quality is often vaguely measured; here we present a thorough investigation of environmental quality at the local level, controlling for individual- and area-level measures. Our findings support a shift in focus away from individual factors and towards altering the landscape of women's decision making contexts when considering behaviours relevant to public health.

KEYWORDS: breastfeeding; maternal investment; environmental quality; life history theory; SES; perception

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2.1 ABSTRACT

Background & Objectives: Breastfeeding is an important form of parental investment with clear health benefits. Despite this, rates remain low in the UK; understanding variation can therefore help improve interventions. Life history theory suggests that environmental quality may pattern maternal investment, including breastfeeding. We analyse a nationally-representative dataset to test two predictions: 1) higher local environmental quality predicts higher likelihood of breastfeeding initiation and longer duration; 2) higher socioeconomic status (SES) provides a buffer against the adverse influences of low local environmental quality.

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Key words: breastfeeding, maternal investment, environmental quality, life history theory, SES, perception

2.2 BACKGROUND & OBJECTIVES

2.2.1 Breastfeeding as maternal investment

The benefits of breastfeeding are well established (Spencer, 2008) with benefits for infants (e.g. reduced risks of developing respiratory diseases, gastrointestinal conditions and various other infections (Chantry et al., 2006; Mårild et al., 2007; Talayero & Lizán-García, 2006)), mothers (e.g. reduced risk of being overweight and developing diabetes and some female cancers (Collaborative Group on Hormonal Factors in Breast Cancer, 2002; Jordan et al., 2010; Kac et al., 2004)) and society (e.g. reduced financial and environmental costs and parents needing less time off to care for sick infants (Khoury et al., 2005, p. 65)). Despite its many benefits, many women in high-income populations do not breastfeed and of those that do, few manage the WHO recommended 6 months of exclusive breastfeeding (World Health Organization, 2015). The UK has particularly poor breastfeeding rates (Victora et al., 2016), inspiring many interventions to improve participation in recent years (L Dyson et al., 2005; UNICEF, n.d.). Breastfeeding is patterned socioeconomically (A. E. Brown et al., 2010), ethnically (Agboado et al., 2010) and geographically (Laura J Brown, 2014), with great disparities across the country.

In the UK's context, whether an infant is breastfed does not represent the same life-and-death situation as it would have done throughout most of human history (Victora et al., 2016). However, there are still advantages to receiving breastmilk: reduced hospital admissions (Talayero & Lizán-García, 2006), better cognitive development (M. S. Kramer et al., 2008) and resilience against psychosocial stress (Holman & Grimes, 2003; Montgomery, Ehlin, & Sacker, 2006). Breastfeeding support groups advocate that every drop of breastmilk counts (Wiessinger, West, & Pitman, 2010) and there is some truth behind this sentiment, with some benefits of breastfeeding being dose-dependent. For example, reductions in hospital admissions for non-perinatal infections are seen for each additional month of breastfeeding (Talayero & Lizán-García, 2006); children exclusively breastfed for as little as 3 months have higher IQ scores than those breastfed for less than 3 months, and scores are higher when breastfeeding is maintained for longer (M. S. Kramer et al., 2008). Even one day of breastfeeding has benefits, with colostrum being particularly valuable for newborns (Holman & Grimes, 2003; UNICEF, 2002). Breastfeeding initiation and duration are not just relevant to public health (Rollins et al., 2016; Unicef UK Baby Friendly Initiative, 2016; Victora et al., 2016), but also important indicators of parental investment in offspring quality.

Life history theory emphasises trade-offs in energetic resources across the lifespan, including those surrounding parental investment (S. Stearns, 1989) and thus the framework helps to understand differences in breastfeeding behaviour within populations, and might help to explain the variation seen in the UK. Breastfeeding is energetically costly for mothers, requiring twice as much daily energy as gestation (McDade & Worthman, 1998). It is additionally time-consuming and can prevent mothers from engaging in other activities (Pat Hoddinott et al., 2012; McDade & Worthman, 1998). Like other depreciable forms of parental investment, breastfeeding necessarily affects the amount of resources available for women to invest in their own growth or future reproduction, or caring for other current offspring and assisting other kin (Quinlan et al., 2003). As such, women must make trade-offs regarding the level of investment to provide through lactation (Tracer, 2009). For example, shortened breastfeeding duration may reflect a (conscious or unconscious) decreased investment in the current offspring in favour of being able to reproduce again soon (Lienard, 2011; Nettle, 2009), while extended breastfeeding durations may indicate higher investment. This is not to imply a qualitative judgement of women's parenting decisions, or to say that women who do not breastfeed are investing less in their offspring, but rather to acknowledge breastfeeding as one of several ways in which mothers can invest in their children.

Breastfeeding may not be a very straightforward predictor of parental investment, however, especially in high-income contexts. Women may feed a child formula rather than breastmilk, not through any deliberate reduction of parental investment, but to allow investment in other ways, e.g. economically rather than energetically. It isn't clear how women weigh up the relative costs of feeding their children. Deciphering this trade-off may be especially complex for well-nourished women where gaining sufficient calories to breastfeed is not a problem.

In our evolutionary past, not breastfeeding an infant would almost certainly result in death. Such complete withdrawal of lactational investment may not have been common, but every woman would have faced decisions about how long to breastfeed for. Given lactational amenorrhoea's role in preventing subsequent pregnancy (Chowdhury et al., 2015; Kennedy, 2005), reducing or stopping breastfeeding would have been an effective way of reallocating investment, shifting focus from current offspring to future reproduction (Ellison, 2003). Decisions about whether and for how long to breastfeed may therefore have been crucial for allocating maternal investment optimally between children. Such decisions are underpinned by evolved psychological and physiological mechanisms which may still have behavioural consequences in the evolutionarily-rare context of minimal breastfeeding we see in many high-income societies today.

2.2.2 Life history theory and environmental influences on reproductive strategies

Life history trade-offs are influenced by one's environment (H. S. Kaplan & Gangestad, 2012), and more specifically 'environmental quality'. Two key components of 'environmental quality' are resource access and extrinsic mortality risk.

Resource availability affects women's overall energy budget. Individuals with larger budgets are able to invest more in both parental care *and* fertility (Caudell & Quinlan, 2012; H. S. Kaplan & Gangestad, 2012). Resource access can refer to extra-somatic resources (e.g. income, education and job status), as well as embodied capital gleaned form support networks (Snopkowski & Kaplan, 2014). Social support (Karb, Elliott, Dowd, & Morenoff, 2012; Robinette et al., 2013) may be a particularly important resource in a social, cooperatively breeding species such as ours (K. L. Kramer, 2010). Resources can also be somatic i.e. an individual's condition, with physiological and psychological quality likely affecting trade-off decisions.

Extrinsic mortality risk, i.e. risk not dependent on an organism's own behaviour (S. C. Stearns, 1992), also shapes life history trade-offs: individuals in higher mortality environments are predicted to have relatively early births (Placek & Quinlan, 2012) and more births (Strassmann & Gillespie, 2002; Stulp & Barrett, 2015), in order to achieve reproductive success before dying (although see (Quinlan, 2010) for descriptions of non-linear associations). Lower parental investment per offspring may also be a characteristic of high extrinsic mortality risk (Quinlan, 2007) – though this is likely confounded by lower resource access.

It is hard to measure extrinsic mortality risk and resource access/scarcity separately, and our analysis cannot disentangle these two components of environmental quality. Our aim instead is to understand environmental influences in more detail by measuring environmental quality at various levels, focusing on localised, subjective experience and exploring the possible distinction between sociocultural and physical aspects of the environment. We use three sets of indicators of both resource access and extrinsic mortality risk: area-level environment, local environment, and individual socioeconomic status (SES). We now briefly discuss how environmental quality has been operationalised in other studies before presenting our approach.

2.2.3 Operationalising environmental quality

Environmental quality is not a concept unique to the life history literature, but is also used in public health, psychology and anthropology to contextualise and explain human behaviour. In high income populations (where most of this research has been done), environmental quality consistently correlates with a wide range of health outcomes and behaviours from chronic diseases and the aging process, to mental health and social well-being (Carter, Williams, Paterson, & Iusitini, 2009; Diez Roux, 2007; Galea et al., 2007; Park et al., 2015; Pickett & Pearl, 2001; Robinette et al., 2013). It predicts patterns of reproductive behaviours and outcomes, with not just earlier first births and more births, but also preterm deliveries, smaller for gestational age and lower birthweight babies common in poor quality environments (Agyemang et al., 2009; Morello-Frosch & Shenassa, 2006; Nettle, 2010a; Pearl, Braveman, & Abrams, 2001; Schempf, Strobino, & O'Campo, 2009; Tenfelde, Finnegan, Miller, & Hill, 2012). Links with parenting strategies have been less well explored (though see Ellison, 2003) but it is likely that breastfeeding, a form of parental investment and important health behaviour, may be similarly amenable to environmental influence (Quinlan, 2010).

What constitutes a poor quality environment is variably defined, not always well operationalised, and often measured crudely at the aggregate-level. Poorer quality environments can be thought of as having more social and physical environmental problems and less social cohesion (Auger et al., 2008; Avan & Kirkwood, 2010; Buka, Brennan, Rich-Edwards, Raudenbush, & Earls, 2002) and as being less safe than higher quality environments (Curtis, Dooley, & Phipps, 2004). Physical and sociocultural aspects of environmental quality are sometimes conflated (Rollings et al., 2015), but distinctions can help clarify which specific attributes are predictive of different health outcomes (Auger et al., 2012; Ellen, Mijanovich, & Dillman, 2001; Johns, 2011; Karb et al., 2012). We conceptualise environmental quality in two main ways: sociocultural environmental quality includes how people in the local area behave towards each other, for example how supportive and friendly people are or whether there are signs of crime and antisocial behaviour; while physical environmental quality captures the built environment as well as notions of cleanliness and pollution.

Environmental quality is often measured as area-level SES, with the Index of Multiple Deprivation (IMD) used most often in UK breastfeeding research. Other measures used include the Child Poverty Index (Bartington et al., 2006) and council tax valuation bands (Beale et al., 2006). Although measured at lower spatial scales, the IMD is typically presented as an aggregate measure at the ward-level. IMD studies present mixed results, with higher levels of deprivation linked to earlier breastfeeding cessation in some studies (A. E. Brown et al., 2010; Oakley, Henderson, et al., 2014) but not others (Agboado et al., 2010). Nettle et al., for example, found that women in the most deprived neighbourhoods breastfed their infants for almost 3 months less than those living in less deprived areas (Nettle, 2010a, p. 391). These findings support life history theory predictions, but localised measures of environmental quality may better capture an individual's actual experience than crude approximations based on aggregated area-level measures (Curtis et al., 2004; Johns, 2011).

2.2.4 The role of subjective environmental experience and environmental perception

There has been a recent shift towards using respondents' own assessments of environmental quality instead of aggregate-level proxies (Carter et al., 2009). As with the more objective measures of environmental quality, individual environmental perception correlates with several reproductive behaviours (Chisholm, Quinlivan, Petersen, & Coall, 2005; Johns, 2011; Johns et al., 2011): women have lower birth weight babies (Auger et al., 2008; Nettle, 2010a) and earlier first births (Johns, 2011; Nettle, 2010a) when they *perceive* their environments unfavourably. Parenting strategies are similarly affected; *subjective experience* of mortality (as measured by number of children lost under the age of 15) negatively predicts maternal involvement with offspring (Fouts & Silverman, 2015). Subjective environmental quality is also more strongly linked to some health outcomes than objective environmental quality (Auger et al., 2008; Carter et al., 2009; Curtis et al., 2004), but researchers emphasise the need to explore both kinds of measure to gain a more comprehensive understanding of links between the environment, behaviours and health outcomes (Auger et al., 2008; Rollings et al., 2015).

2.2.5 SES as marker of individual condition and a buffer to environmental insults

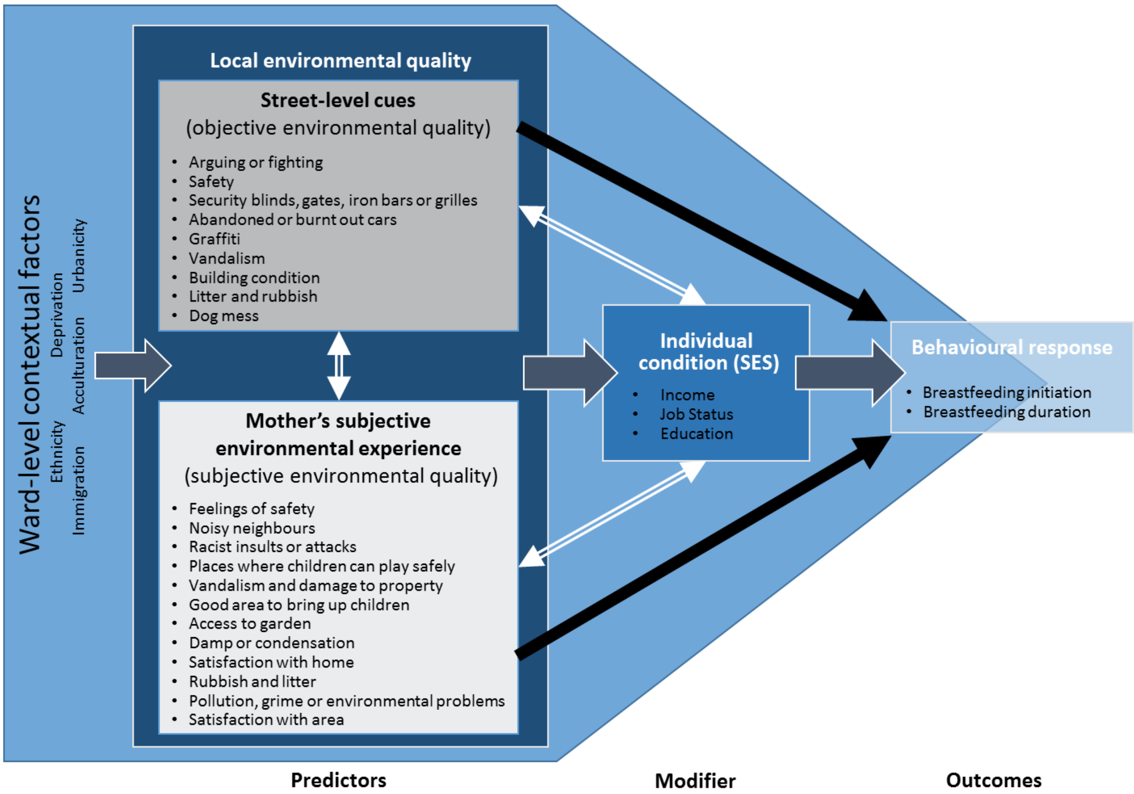
In contemporary high-income countries, evolutionary researchers need to take into consideration heterogeneity and stratification in the populations they study, especially in large and economically unequal societies such as the UK (Schaffnit & Sear, 2014; Stulp, Sear, & Barrett, 2016; Stulp, Sear, Schaffnit, Mills, & Barrett, 2016). SES, however, is a biologically problematic construct, more readily explained culturally than with biology (Wiley & Cullin, 2016). In evolutionary studies, it has been conceptualised as representing an individual's condition (which may incorporate 'scarring' from living in a high extrinsic mortality environment) (Rickard, Frankenhuis, & Nettle, 2014; Stringhini et al., 2017; Wander & Mattison, 2013) or a marker of the resources a parent has (Quinlan et al., 2005). As such, teasing apart individual and environmental components of mortality risk or resource access becomes tricky. However, individual condition and resource access may influence the trade-offs mothers make regarding how best to invest their resources, over and above environmental factors and vice versa (Nettle, Frankenhuis, & Rickard, 2013; Pickett & Pearl, 2001; Rickard et al., 2014). For example, people in poor communities may experience a "double jeopardy" where socioeconomic stressors interplay with environmental hazards to have negative impacts on health, while those with higher SES are protected against environmental insults by virtue of their greater access to resources and better condition (Frankenhuis & Panchanathan, 2011b, 2011a; Morello-Frosch & Shenassa, 2006; Schüle & Bolte, 2015). We therefore additionally conceptualise individual SES as a means to buffer against risks posed by low environmental quality – as judged both subjectively and objectively.

2.2.6 Aims and hypotheses

The overall aim of the study is to investigate whether localised measures of environmental quality are associated with breastfeeding initiation and duration, and to tease apart the influence of local environmental experience and individual SES on women's investments in breastfeeding in the UK. We will address this by testing two main hypotheses:

1. Local environmental quality is positively correlated with the probability of breastfeeding initiation and lengthened breastfeeding duration;
2. Higher individual SES buffers against negative effects of lower local environmental quality on breastfeeding.

Figure 2.1 Conceptual framework



This figure shows how we conceptualised relationships between environmental quality, socioeconomic status and breastfeeding outcomes, and how we operationalised them in statistical models. White double-headed arrows represent predicted interactions. Black single-headed arrows represent predicted positive associations. The wide dark grey arrows represent assumed links not explicitly tested in our models. We constructed objective environmental *quality and subjective environmental quality scores based on a factor analysis of independent neighbourhood assessments and mother's survey responses: bullet points show the items each measure is comprised of.*

In acknowledgement of the potential influence of larger-scale environmental factors, we also consider area-level environmental quality (measured by IMD) and other contextual factors in our models to isolate local level influences on breastfeeding, above and beyond wider-scale deprivation. Our conceptualisation of the layers of environmental influence on women's breastfeeding behaviours is shown in Figure 2.1.

2.3 METHODS

2.3.1 Sample

The Millennium Cohort Study (MCS) is an ongoing longitudinal study following the lives of around 19,000 children born in the UK between 2000 and 2002 (UCL Institute of Education, 2015; for a full cohort profile see Connelly & Platt, 2014). We use information collected in the first and second waves, where children were around 9 months and 3 years old respectively (UCL Centre for Longitudinal Studies, 2012b, 2012a). Geographical boundary data provide larger-scale environmental influences at the ward/superward level (UCL Centre for Longitudinal Studies, 2015a, 2015b). We restricted the sample to biological mothers still living with their children and, where mothers had twins or triplets, we only included data from one child (Cohort Member 1). Samples were further restricted to mothers who completed both waves of data collection. This gave us a maximum usable sample size of 14,576 mothers.

2.3.2 Variables

2.3.2.1 Outcomes

Breastfeeding initiation was measured retrospectively by asking mothers whether they had ever tried to breastfeed, and duration was captured by asking the age at which the infant had last received breastmilk. Initiation does not therefore confirm breastfeeding success nor is duration necessarily limited to exclusive breastfeeding. Both outcomes were measured in Wave 1 and some mothers were still breastfeeding at the time of this survey.

2.3.2.2 Predictors

We used weighted iterated principal factor analysis with oblique promax rotation to create summary measures of environmental quality (Dean, 2009; IDRE, Institute for Digital Research and Education, n.d.). We included 29 items (listed in Table 2.1) chosen to reflect both physical and sociocultural aspects of the environment: 19 from interviews with mothers; and 10 from neighbourhood assessments.

2.3.2.2.1 Interview items

Mothers were asked questions regarding their local area ("within about a mile or 20 minutes' walk" (National Centre for Social Research, 2003)) and their home. 17 of the 19 items were taken from the first wave and the other two from the second wave. These items provide a balanced spread of an individual's own environmental experience: focussing on both the immediate environment (the home) and the external broader local environment (the self-defined local area); and include both physical and sociocultural information.

2.3.2.2.2 Neighbourhood Assessment items

Supplementary neighbourhood observations were carried out during Wave 2 of the MCS as part of an evaluation of The National Evaluation of the Children's Fund (Hansen, 2012). Non-resident observers responded to 11 questions about the general state of the neighbourhood and reported how safe they felt for each visit they made to the household (Edwards, Barnes, Plewis, & Morris, 2006; UCL Centre for Longitudinal Studies, n.d.). We included all but one of these measures in our factor analysis (traffic calming excluded due to a high level of missingness at 60.1%). Households were visited on several occasions, with the majority being visited two or three times and some being visited as often as 15 times (Edwards et al., 2006). We created an average score for each item across all visits to account for any time-based variation. Unlike the interview items relating to a mother's own perception and experience of her environment, these neighbourhood assessment items reflect a more objective account of the local area. For example, assessors are likely to have calibrated their assessments through exposure to multiple neighbourhoods during the study wave. These neighbourhood observations have been shown to map well on to both how disadvantaged an area is (as defined by the Child Poverty Index) and the criteria used to allocate Children's Fund programmes (Edwards et al., 2006), lending further support to their use in creating an objective measure of environmental quality.

2.3.2.2.3 Factor analysis

Prior to analysis, we had expected the interview and neighbourhood assessment items to represent the same underlying construct of local environmental quality with perhaps distinct physical and sociocultural dimensions emerging. However, based on eigenvalues over 1 (Kaiser, 1960), the two factors that were identified could be better considered as relatively more objective and relatively more subjective indicators of environmental quality. Objective items were entirely reported by the neighbourhood assessor and subjective entirely by the mother. The factor loadings are shown in Table 2.1.

Only items with factor loadings above 0.3 were included in the measures, resulting in twelve being included in the subjective measure and nine in the objective measure. Whether the mother thought that she lived in a good area to bring up children loaded on to both factors, but we decided to only include it in the subjective measure as this was a response provided by the mother, not the neighbourhood assessor. Eight variables did not load on either factor and we test their relationships with breastfeeding outcomes in separate models (results shown in Appendix A).

Confirmatory factor analysis was then used to predict objective and subjective environmental quality factor scores. The Cronbach's alpha coefficient was 0.81 for the subjective and 0.80 for the objective measure indicating good inter-item reliability.

2.3.2.2.4 SES

As SES can be variably defined and measured, we opted to use three indicators: income, job status and education. We ran separate sets of models for each indicator, and one set of models including all three. Income was equivalised to take account of household composition. Job status was measured by the National Statistics Socio-economic Classification and education by highest qualification level. We combined academic and vocational qualifications into one variable using the information on the government's education and learning page (GOV.UK, 2016). For partnered mothers, the higher job status and qualification level of her and her partner was used.

There were some differences between the different SES model versions but none that affected our substantive conclusions. We therefore focus mainly on results from the income models, presenting models using the other indicators in the supplementary material.

2.3.2.3 Covariates

2.3.2.3.1 Exposure to current environment

We included time at current address and whether women moved house between waves to control for duration of exposure to current environment. We acknowledge that for those who moved house their former environment may have been different from their current environment. On average we might expect the two environments to be relatively similar (with some women moving to higher quality areas, others to lower quality areas and many to areas of similar quality). The vast majority of women would've stopped breastfeeding in the interval between Wave 1 (when the child was 9 months old) and Wave 2 (3 years old) and so we largely avoid the issue of using a new environment to predict past behaviour. We ran models with a restricted sample (non-movers only; not shown) but found substantively similar results, with similar-sized effects going in the same direction and with similar levels of significance.

2.3.2.3.2 Infant and maternal characteristics

We included several infant and maternal characteristics known to be important for predicting breastfeeding outcomes: birthweight (Furman, Minich, & Hack, 1998), maternal age (Sloan et al., 2006), partnership status (Kiernan & Pickett, 2006), parity (Bartington et al., 2006; Ma & Magnus, 2012; Oakley, Kurinczuk, Renfrew, & Quigley, 2014), ethnicity (Y. J. Kelly et al., 2006), immigration and acculturation (Hawkins, Lamb, Cole, & Law, 2008).

Maternal age was coded into roughly 10-year age bands. We used number of parents/carers in the household as a proxy for partnership status, although some mothers may be partnered but not cohabiting. We used number of siblings of cohort member in household as our parity measure, although we note that this may underestimate parity for cases where children have left the family home. Ethnicity was coded into four categories due to small sub-group sizes. We chose cohort member ethnicity rather than mother's ethnicity to capture the combination of maternal and paternal ethnicity-related influences on breastfeeding. Immigration status was derived from respondent's place of birth and their parent's place of birth and coded into born in the UK, second generation, first generation (arrived as child) and first generation (arrived as adult) to reflect varying degrees of cultural assimilation. Language(s) other than English spoken at home was used a measure of acculturation. Birthweight was categorised as low, normal or high.

2.3.2.3.3 Contextual factors

We included several contextual factors in our models to isolate local level influences on breastfeeding, above and beyond wider-scale deprivation. Our conceptualisation of the layers of environmental influence on women's breastfeeding behaviours is shown in Figure 2.1.

Ward-level IMD scores accounted for larger-scale environmental influences and weighted ward-level proportions of immigrants, speakers of other languages, black and ethnic minorities, and people living in urban areas controlled for geographical sociocultural variation. Immigration composition was derived by calculating the proportion of women who were born in the UK and whose parents were born in the UK for each ward and using its inverse to calculate the proportion that could be classified as immigrants. For language composition we calculated the proportion of people in each ward that spoke only English and used its inverse to give a proportion of people who either spoke English and another language or just another language at home. Similarly, ethnic composition was created by taking the inverse of the proportion of White mothers by ward. The urban proportion was simply the average number of people living in urban areas by ward and for IMD we used the weighted mean score by ward.

2.3.3 Analyses

We used logistic regression to investigate associations between our two local environmental quality measures and the probability of initiating breastfeeding. For breastfeeding duration, continuous-time event history analyses accounted for the right-censored nature of the data with analyses necessarily restricted to mothers who reported initiating breastfeeding (n=12,182). Time to termination of breastfeeding was measured in months. Based on the shape of the hazards for stopping breastfeeding, we used the Weibull distribution, allowing hazards to increase and decrease smoothly over time (Hamilton, 2004, p. 305, p305). We checked for the suitability of this approach by testing for interactions between all predictor variables and time (Hamilton, 2004, p307) and checked that the proportional hazards assumption was verified (Kirkwood & Sterne, 2003, p282).

Mixed-effects models were used for both outcomes to account for the hierarchical structure of the data, with individual mothers (all only included in the analysis once) clustered within set wards/superwards. The random effect for ward/superward accounted for unmeasured variability due to higher-level environmental factors. All analyses were weighted using MCS Wave 2 sample weights to account for the stratified clustered sampling design and drop out between waves (Ketende & Jones, 2011). Analyses were conducted in STATA/SE v.14.0 within the UK Data Service's Secure Lab (UK Data Service, n.d.).

To test whether local environmental quality is positively correlated with the probability of breastfeeding initiation and duration (H1), we ran models for each breastfeeding outcome, including each of our environmental quality measures separately, adjusting for (1) maternal and infant characteristics, (2) SES and (3) contextual ward-level factors. Given that infant feeding is ultimately an individual decision, we built our model up in this way to test whether individual-level factors remained associated with breastfeeding outcomes once the larger-scale environmental factors had been accounted for. We present results from this fully-adjusted model and show model progression in the supplementary material (Table A.3 and Table A.4 in Appendix A). To test whether higher SES buffers against negative effects of lower local environmental quality on breastfeeding (H2), we tested for interactions between SES and environmental quality in the fully-adjusted models. We considered there to be evidence of an interaction when the Wald Test $p \leq 0.05$. Significant interactions are presented graphically.

Table 2.1: Factor analysis results: pattern matrix with rotated factor loadings

Item	Source	Factor 1 Objective Environmental Quality	Factor 2 Subjective Environmental Quality	Uniqueness	Aspect
Support sought since birth	S1 MAIN	0.1357	-0.0401	0.9854	Socio
Frequency spends time with friends	S1 MAIN	-0.0049	0.0450	0.9982	Socio
Other parents can talk to	S1 MAIN	0.0982	0.1656	0.9469	Socio
Noisy neighbours	S1 MAIN	-0.0594	**0.6999**	0.5477	Socio
Racist insults or attacks	S1 MAIN	-0.0859	**0.7242**	0.5297	Socio
Any places where children can play safely	S1 MAIN	0.1057	**0.3146**	0.8570	Socio
Feelings about neighbour friendliness	S1 MAIN	0.0453	0.2955	0.8974	Socio
Access to garden	S1 MAIN	0.1589	**0.4018**	0.7502	Phys
Central heating in house	S1 MAIN	0.1357	0.1891	0.9204	Phys
Damp or condensation	S1 MAIN	0.1043	**0.3212**	0.8528	Phys
Satisfaction with home	S1 MAIN	0.0471	**0.4885**	0.7364	Phys
Rubbish and litter	S1 MAIN	0.0082	**0.7746**	0.3937	Phys
Vandalism and damage to property	S1 MAIN	-0.0224	**0.7948**	0.3854	Socio/Phys
Poor public transport	S1 MAIN	-0.1250	0.1680	0.9769	Socio/Phys
Food shops in easy access	S1 MAIN	-0.0197	-0.0489	0.9963	Phys
Pollution, grime, environmental problems	S1 MAIN	-0.1056	**0.6491**	0.6353	Phys
Satisfaction with area	S1 MAIN	-0.0074	**0.6986**	0.5170	Socio
How safe feel in area	S2 MAIN	0.2274	**0.3655**	0.7325	Socio
Good area to bring up children [a]	S2 MAIN	**0.3488**	**0.3978**	0.5829	Socio
General condition of buildings on the street	S2 NA	**0.7557**	0.0883	0.3552	Phys
Security blinds etc.	S2 NA	**0.7144**	0.0184	0.4763	Socio
Volume of traffic	S2 NA	0.1498	-0.0034	0.9781	Phys
Burnt out cars on the street	S2 NA	**0.5715**	-0.1485	0.7352	Socio/Phys
Litter etc. in the street or on the pavement	S2 NA	**0.8105**	0.0498	0.3007	Phys
Dog mess on the pavement	S2 NA	**0.7619**	-0.1271	0.4991	Phys
Graffiti on walls or in public spaces	S2 NA	**0.8866**	-0.0682	0.2691	Socio/Phys
Evidence of vandalism	S2 NA	**0.9211**	-0.1428	0.2611	Socio/Phys
Arguing or fighting on the street	S2 NA	**-0.3872**	-0.1154	0.7927	Socio
Observer feeling in the street	S2 NA	**0.7895**	0.1246	0.2639	Socio

Factor loadings greater than 0.3 were included in the main environmental quality measures and are shown in bold. Items loaded on to two factors. Weighted n=16,954. S1 MAIN: mothers' answers to main survey carried out when child was ~ 9 months old. S2 MAIN: mothers' answers to main survey carried out when child was ~ 3 years old. S2 NA: second survey neighbourhood observations. Socio: Sociocultural environment. Phys: Physical environment. Cronbach's alpha coefficients: Factor 1=0.80, Factor 2=0.81. [a] This item loaded onto both factors but was only used in the subjective environmental quality measure as it was reported by the mother not the neighbourhood assessor.

2.4 RESULTS

2.4.1 Characteristics of study sample

69.44% of mothers reported initiating breastfeeding and the mean duration was 2.70 months (SD 3.49) (Table 2.2). The lowest breastfeeding initiation rates and durations were found in women with low subjective (64.84% and 2.35 months) and objective

(60.29% and 2.08 months) environmental quality scores. The environmental quality variables that did not load on to the two main measures were generally similarly associated with breastfeeding outcomes, with mothers in poorer quality environments exhibiting reduced breastfeeding behaviour. In terms of ward-level environmental quality, women who didn't initiate breastfeeding shared similar characteristics to those who did initiate but had the shortest breastfeeding duration. They were more likely to live in an area with few black and ethnic minority and immigrant inhabitants, and few people who didn't speak English; and they were more likely to live in an urban and more-deprived area. Additional descriptive statistics can be found in

Table A.2 Table A.2 in Appendix A.

2.4.2 Model results

As the model covariates are all well-established risk factors in the breastfeeding literature, we do not discuss their relationships with the breastfeeding outcomes further here, and return our focus to our localised measures of environmental quality.

2.4.2.1 H1. Associations between local environmental quality and breastfeeding outcomes

2.4.2.1.1 Subjective environmental quality

Subjective environmental quality was positively associated with breastfeeding initiation when controlling for maternal and infant characteristics: a 1-point increase in subjective environmental quality predicted 12.5% greater odds of breastfeeding initiation (CI 1.026-1.234). Subjective environmental quality did not however predict breastfeeding initiation once SES and/or ward-level contextual factors were accounted for (Table 2.3; see Table A.4 for model progression). Results did not vary according to the SES indicator used (Tables A.5, A.6 and A.7). We also tried adding just IMD (or IMD plus the other ward-level factors) but not SES to the models (results not shown). This also made the relationship between subjective environmental quality and breastfeeding initiation disappear suggesting that both individual and broader-level measures may be better measures of environmental quality than our more localised measure of environmental perception.

For breastfeeding duration, hazard ratios are interpreted as the probability of stopping breastfeeding. We found (weak) evidence that higher subjective environmental quality correlated with lengthened breastfeeding duration after controlling for all covariates.

Table 2.2: Descriptives for key variables

		Breastfeeding	
	n	**Initiation (n(%))**	**Duration in months (Mean (SD))**
Environmental quality:			
Subjective Environmental Quality* **			
Low	5,038	3,266 (64.84%)	2.35 (3.37)
Middle	4,543	3,192 (70.28%)	2.77 (3.52)
High	4,576	3,347 (73.14%)	2.98 (3.56)
Objective Environmental Quality* **			
Low	5,580	3,360 (60.29%)	2.08 (3.24)
Middle	4,362	3,095 (70.99%)	2.75 (3.51)
High	4,173	3,329 (79.79%)	3.46 (3.63)
Individual condition (SES):			
Income (OECD equivalised quintiles)* **			
Lowest	3,271	1,753 (53.61%)	1.67 (3.01)
Second lowest	3,153	1,950 (61.87%)	2.12 (3.26)
Middle	2,815	1,972 (70.05%)	2.69 (3.54)
Second highest	2,742	2,186 (79.72%)	3.34 (3.62)
Highest	2,555	2,230 (87.28%)	4.06 (3.57)
Job status (NS-SEC)* **			
Not applicable	1,027	587 (57.38%)	2.04 (3.30)
Routine and manual	4,810	2,647 (55.09%)	1.56 (2.84)
Intermediate	2,775	1,914 (69.00%)	2.50 (3.44)
Higher managerial, admin, professional	5,964	4,966 (83.28%)	3.82 (3.69)
Education (highest qualification)* **			
None	2,396	1,294 (54.05%)	1.79 (3.13)
Level 1 or 2	5,289	3,178 (60.09%)	1.80 (2.98)
Levels 3 to 5 (inc. others and overseas)	3,071	2,262 (73.66%)	2.85 (3.48)
Level 6 plus	3,789	3,365 (88.81%)	4.42 (3.72)
Total [a]		10,114 (69.44%)	2.70 (3.49)

*Unweighted. N=14,576. Pearson Chi^2 comparing proportion initiating breastfeeding across categories: ***p≤0.001. SES: socioeconomic status. OECD=Organisation for Economic Co-operation and Development. NS-SEC=National Statistics Socio-economic Classification. [a] Initiation data missing for 11 mothers.*

A 1-point increase in subjective environmental quality predicted a 5.3% reduction in the odds of termination per month (CI 0.896-1.001). However, we have little confidence in this relationship as the effect size was small and the relationship disappeared in models when alternative SES indicators were used (Table 2.3 and **Table A.5**Tables A.5, A.6 and A.7).

2.4.2.1.2 Objective environmental quality

Objective environmental quality positively predicted both breastfeeding initiation and duration. In the fully-adjusted model, a 1-point increase in objective environmental quality predicted 53.7% greater odds of breastfeeding initiation and a 14.1% reduction in the odds of breastfeeding termination per month (Table 2.3).

Table 2.3: Associations between subjective and objective environmental quality measures and breastfeeding outcomes

	Initiation			Termination		
	Odds Ratio	**95% Confidence Interval**	**P-value**	**Hazard Ratio**	**95% Confidence Interval**	**P-value**
Subjective Environmental Quality	0.964	0.880-1.057	0.438	0.947	0.896-1.001	***0.056***
Income (OECD equivalised quintiles)			**<0.001**			**<0.001**
Lowest	1.000	(ref.)	.	1.000	(ref.)	.
Second	1.156	0.929-1.437	0.193	0.905	0.791-1.036	0.149
Middle	1.599	1.263-2.024	**<0.001**	0.811	0.712-0.923	**0.002**
Fourth	2.382	1.862-3.046	**<0.001**	0.775	0.682-0.882	**<0.001**
Highest	2.704	1.970-3.710	**<0.001**	0.765	0.673-0.869	**<0.001**
Constant	0.354	0.198-0.632	**<0.001**	1.054	0.759-1.463	0.754
N	13,852			9,620		
Objective Environmental Quality	1.537	1.229-1.922	**<0.001**	0.859	0.766-0.965	**0.010**
Income (OECD equivalised quintiles)			**<0.001**			**0.002**
Lowest	1.000	(ref.)	.	1.000	(ref.)	.
Second	1.072	0.870-1.322	0.513	0.941	0.821-1.078	0.381
Middle	1.411	1.126-1.768	**0.003**	0.844	0.738-0.966	**0.014**
Fourth	2.006	1.570-2.563	**<0.001**	0.800	0.699-0.916	**0.001**
Highest	2.181	1.587-2.999	**<0.001**	0.782	0.685-0.893	**<0.001**
Constant	0.092	0.041-0.206	**<0.001**	1.346	0.898-2.017	0.150
N	13,737			9,561		

Each model includes one environmental quality measure only. Models are adjusted for exposure to current environment, infant and maternal characteristics, income and ward-level contextual factors. P-values ≤0.05 shown in bold and p-values between 0.05 and 0.1 shown in bold italic. Hazard ratios represent breastfeeding termination rather than duration. The number of observations (N) varies between models due to differing levels of missing data. Results weighted to allow for complex survey design and models are hierarchical to control for clustering at ward-level. OECD=Organisation for Economic Co-operation and Development.

The effect sizes varied slightly when alternative SES measures were used and only breastfeeding initiation remained significantly associated with objective environmental quality in all three other SES model versions (see Tables A.5, A.6 and A.7). The equivalent estimates ranged from 29.6 to 53.5% for initiation and 3.7 to 10.7% for duration. For full model results, including estimates for all control variables and random effects, see Table A.3.

2.4.2.1.3 Other environmental quality indicators

Some of the extra environmental quality variables that did not load onto the two main measures had significant associations with breastfeeding outcomes in their own right, with some remaining predictive of breastfeeding outcomes even after controlling for the summary environmental quality measures and across all SES versions (Tables A.4, A.5, A.6 and A.7). The items with the strongest evidence for relationships with breastfeeding outcomes were support sought since birth, having other parents to talk to and spending time with friends, with some evidence also suggesting that neighbour friendliness and central heating may also predict breastfeeding. Associations were largely in the predicted directions of environmental quality positively predicting breastfeeding. We found little to no evidence to suggest that public transport, access to food shops and volume of traffic predicted breastfeeding outcomes and so do not consider these results further. We discuss model results for the other five items in more detail in the supplementary material.

2.4.2.2 H2. Does individual SES buffer the effects of environmental quality on breastfeeding outcomes?

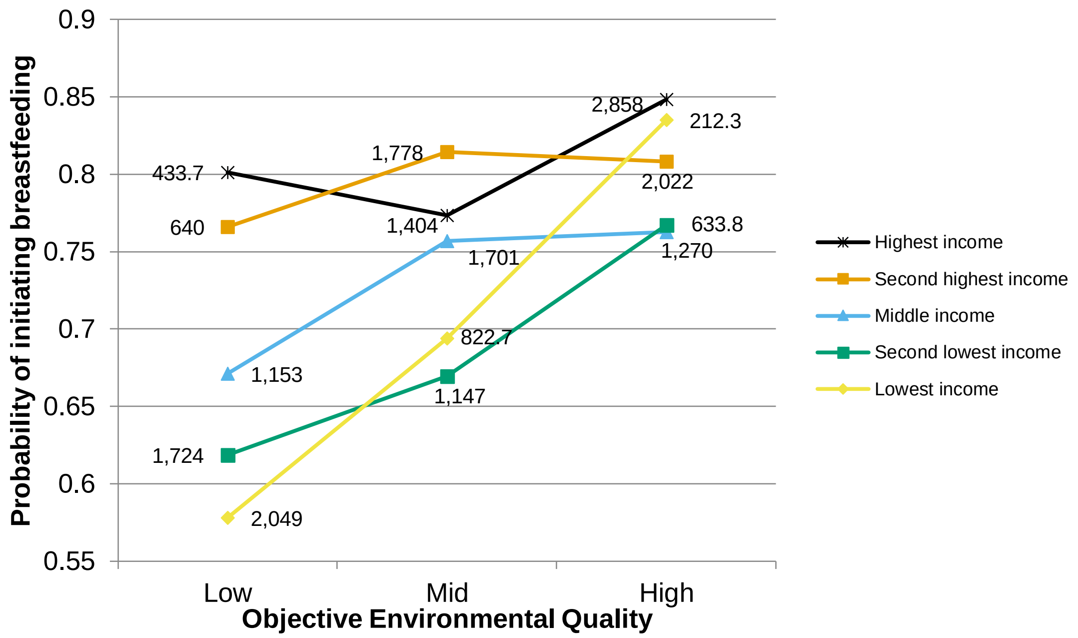
2.4.2.2.1 SES interactions with local environmental quality

In fully-adjusted models, the odds of initiating breastfeeding increase with income; women in the highest income quintile have 2.2-2.7 times the odds of initiation compared to those in the lowest quintile (Table 2.3). Similarly, the hazard of stopping breastfeeding decreases with income, with hazards 77-78% lower for women in the highest income quintile compared to those in the lowest quintile (results for other SES measures shown in Tables A.5, A.6 and A.7).

Subjective environmental quality did not interact with any of the SES indicators to predict breastfeeding initiation. For breastfeeding duration, we found weak evidence for an interaction between subjective environmental quality and income ($p=0.068$). Higher-income women had relatively high probabilities of maintaining breastfeeding regardless of subjective environmental quality, while women with lower incomes had higher odds of breastfeeding with higher subjective environmental quality scores.

Objective environmental quality interacted with income to predict breastfeeding initiation (Figure 2.2, $p=0.013$) and with job status to predict breastfeeding duration (Figure 2.3, $p=0.045$), but not other SES indicators. Although we did not find interactions across all SES indicators and for both breastfeeding outcomes, taken together the two interactions provide some evidence that high SES may buffer against environmental insults.

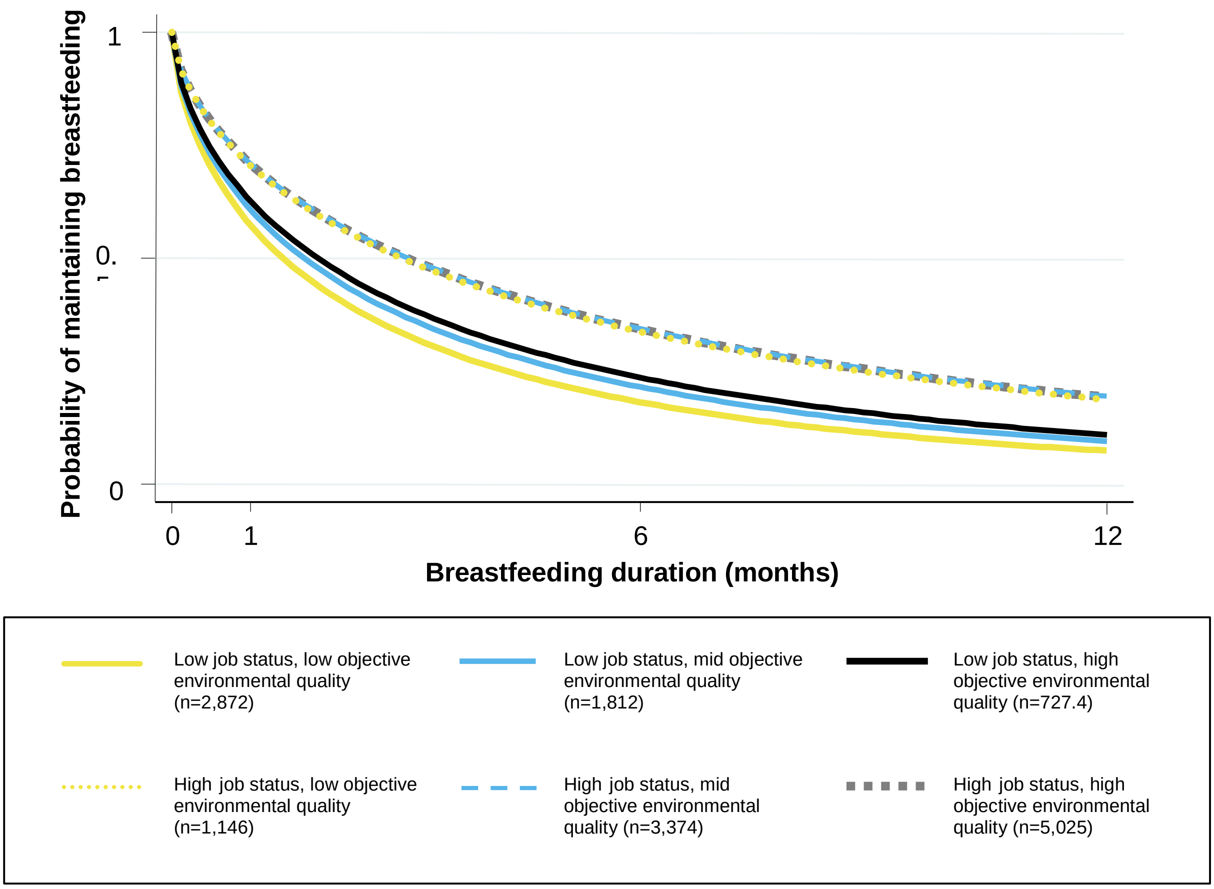
Figure 2.2: Breastfeeding initiation by income and objective environmental quality



Predicted probabilities from model controlling for exposure to current environment, infant and maternal characteristics, income and ward-level contextual factors and accounting for both fixed and random effects. N=13,737. Interaction p=0.013. All categorical covariates held at modal values and continuous covariates held at median values. Data labels are weighted counts for each group.

Mothers from higher-income households had relatively high breastfeeding initiation rates regardless of objective environmental quality; while breastfeeding initiation was more strongly positively correlated to objective environmental quality in lower-income households. Similarly, mothers from households with high job status were likely to maintain breastfeeding regardless of their objectively-assessed environmental conditions; while the probability of maintaining breastfeeding decreased with lower objective environmental quality scores for women in households with low job status.

Figure 2.3 Breastfeeding duration by job status and objective environmental quality



Predicted probabilities of breastfeeding duration to 12 months by job status and objective environmental quality. Predicted from M6 (controlling for infant and maternal characteristics, income and ward-level contextual factors) and accounting for both fixed and random effects. N=9,573. Interaction p=0.045. All covariates held at mean values. Group ns are weighted counts.

2.5 CONCLUSIONS & IMPLICATIONS

We set out to test whether local environmental quality was associated with breastfeeding and whether individual SES buffers against environmental harshness. We found that local environmental quality did positively predict breastfeeding, but the strength of this association depended on how local environmental quality was measured. We had expected separate measures of local physical and sociocultural quality to emerge from our factor analysis, but these aspects loaded together and items split instead into mother’s own assessments (“subjective environmental quality”) and those made by an independent enumerator (“objective environmental quality”). Objective environmental quality was more strongly related to both initiation and duration than subjective environmental quality. We also found some evidence to suggest that individual condition may buffer against environmental insults at the local level.

Our results build on previous life history work which has suggested a link between higher-level environmental quality (as indicated by the IMD) and breastfeeding behaviour (among other life history outcomes) (Nettle, 2010a). One of the strengths of our study is that the environment was subjectively defined by mothers and measured on a small scale by neighbourhood assessors. By controlling for contextual factors at the ward level, we were able to see whether smaller-scale local environmental quality and perception had an impact on breastfeeding above and beyond the more distant and already established influences of deprivation, urbanicity, and population composition.

2.5.2 Comparing environmental quality measures – is environmental perception important?

The ‘objective’ measure of localised environmental quality was a better predictor of breastfeeding outcomes than the ’subjective’ measure, perhaps surprising as one could expect that mothers’ interview responses would capture actual lived environmental experience better than enumerator assessments (Curtis et al., 2004). This finding also contradicts the environmental perception literature which suggests that subjective environmental quality has stronger links to health outcomes than objective environmental quality (Auger et al., 2008; Carter et al., 2009; Curtis et al., 2004).

But objective environmental quality may have stronger associations with breastfeeding than subjective measures because, in this study, it is a better measure of environmental quality. Even though our measures were positively correlated with one another, there was substantial variation in the extent to which the two measures agreed (weighted correlation coefficient=0.4876), just as agreement between objective and subjective measures in other environmental quality studies has been found to be only low to moderate (Rollings et al., 2015). We note that the subjective measure was significantly positively correlated with breastfeeding outcomes, but only in models excluding individual-level SES and ward-level factors. Individual SES and broader area-level environmental quality may therefore be more salient predictors of breastfeeding than subjective measures; whereas objective measures of the local environment capture something about environmental quality that is not included in individual or area-level measures. This may be because our two measures are better thought of as capturing *perceived* stressors versus *observed* stressors (Karb et al., 2012). Direct measures such as the neighbourhood observations used in our study may capture environmental conditions that are not perceived by residents (Rollings et al., 2015), either because residents have fewer points of comparison than objective observers, and/or because familiarity with an environment affects one's perception of that environment (making poor quality environments less intimidating for example). Further, mother's assessments are also likely prone to recall and social desirability bias.

Alternatively, the construction of the measures may provide an explanation for the differences between their associations with breastfeeding. We were restricted by the available variables in the MCS dataset and the subjective measure may have better represented individual exposure to environmental risk if we had had more data on perceptions of problems, cohesion and safety (three dimensions that may be particularly important for determining health outcomes (Curtis et al., 2004)). It would have also been useful to have more information on exposure to crime (Auger et al., 2008; Uggla & Mace, 2015a). Additionally, it may have been illuminating to include a measure of controllability of environmental stressors (Pepper & Nettle, 2014a) to try and tease out extrinsic and intrinsic risk. Despite its limitations, the subjective measure was based on more items than the more objective measure and it also had slightly greater inter-item reliability (with a Cronbach's alpha coefficient of 0.81 vs 0.80).

Finally, it is also possible that some environmental factors are not particularly salient, and thus not captured by our measure of subjective environmental quality, but may trigger changes in behaviour anyway. This would imply that active environmental perception is not required in order to calibrate reproductive behaviour. We offer stress as a potential mechanism linking environmental quality and breastfeeding.

2.5.2 Stress as a potential mechanism linking environmental quality to breastfeeding

Mothers in lower quality environments may be more likely to experience psychological and/or physiological stress which in turn may impact their ability to breastfeed. Breastfeeding is an intense commitment and requires frequent nursing to be maintained. Having to deal with environmental problems may make mothers less responsive to their infants as their attention is needed elsewhere. Effort spent trying to remedy problematic environmental situations will necessarily deplete finite physiological resources and the mental capacity needed to persevere with breastfeeding.

Rickard et al. provide oxidative stress-related effects on somatic function as an example of how a stressful environment can translate into a depleted internal state (2014). Our weaker subjective measure associations could suggest that environmental information may be embodied through a means other than perception i.e. women may not have noticed that their streets were dirty or that there was a lot of vandalism for example, but their bodies may still have displayed a stress-response all the same. Similarly, pollution may cause damage to the body without the mind being aware that there are any health-impacting molecules in the air.

The possibility of environmentally-induced hormonal and physiological disruption may seem unlikely given the relative stability of the hormonal cascade that results in milk production (Wambach & Riordan, 2016, p89). However, stress as measured by maternal self-reported exhaustion and stress hormone levels after labour has been found to be associated with the delayed onset of lactogenesis (Chen, Nommsen-Rivers, Dewey, & Lonnerdal, 1998) and so the leap from acute stress affecting lactation to chronic stress (i.e. that indicated by poor environmental quality) affecting lactation is perhaps not such a big one. In fact, stress as is manifested by tense, anxious mothers can contribute to the negative cycle of low milk supply and low infant intake. Furthermore, both sociocultural and physical environmental factors have been linked to both a reluctance to breastfeed and a physiological impediment to maintaining and sustaining lactation (Ruvalcaba, 1987; Wambach & Riordan, 2016, p361; Zhu et al., 2012).

2.5.3 The importance of individual condition

Maternal condition and maternal access to resources are important as they influence the trade-offs mothers make regarding how best to invest their energy, including how much to invest in any given offspring. The confounding effect of individual SES on the positive relationship between local environmental quality and breastfeeding is hardly surprising given the well-established socioeconomic differential in breastfeeding in the UK (McAndrew et al., 2012). Although most of the different SES model versions produced comparable results, the fact that some results differed depending on whether we controlled for income, job status, education, or all three SES indicators, supports the notion that these separate elements may reflect different resources a mother has available.

The robust SES-breastfeeding association we observed could be explained in terms of the internal prediction model proposed by Rickard et al (2014). This model suggests that early exposure to psychosocial stress embodies as negative influences on state, which increases morbidity and mortality in adulthood, which in turn calibrates maturation rate. Preparing the body physiologically for breastfeeding may be one component of maturation that can be affected by both current and past environmental exposure influences on internal state.

Sensitivity to environmental conditions is also likely to vary across individuals. Experimental evidence suggests that differential susceptibility may well be patterned by SES (Frankenhuis & Panchanathan, 2011b, 2011a), with people from low SES backgrounds being more reactive to mortality primes than people from high SES backgrounds (Griskevicius, Tybur, Delton, & Robertson, 2011). This chimes with the interactions we found between SES and local environmental quality. We predicted that SES would serve as a buffer against environmental insults, modifying the association between local environmental quality and breastfeeding in harsh environments. Our results supported this to some extent because we found that income and job status interacted with objective environmental quality to predict breastfeeding initiation and duration respectively. A lack of social and economic resources may make mothers especially vulnerable as they are not able to easily compensate for what is missing in their immediate surroundings (Ellen et al., 2001).

2.5.4 Breastfeeding barriers at multiple levels

We focussed on individual and local-level indicators of environmental quality in our analyses and controlled for larger-scale environmental factors to test whether neighbourhood quality and individual experience of the environment can calibrate breastfeeding behaviour. We felt that local-level measures would be more salient than abstract concepts of environmental quality measured in aggregate at higher levels - and thus that they would more accurately capture the cues that women actually process and which trigger behavioural responses. Higher-level environment-breastfeeding links are still likely (A. E. Brown et al., 2010; Nettle, 2010a), but our results provide some evidence that local environmental quality predicts breastfeeding outcomes above and beyond the effects of the wider environment. We believe that there will be both breastfeeding-specific aspects (private, welcoming spaces) and more general attributes (cleanliness, friendliness) of both the local and area-level environment that will influence women's breastfeeding behaviour.

While one of the strengths of this paper is how thoroughly we have investigated environmental quality, there are limitations to our approach. Our two main measures of local environmental quality captured the multiplicity of local environmental experience; mothers do not experience cues in isolation, but rather are exposed to a whole suite of environmental characteristics which are likely to jointly affect individual experience. However, by creating a measure that pools different aspects of environmental quality together, we cannot fully identify which specific aspects of the local environment should be targeted for improvement in interventions; identifying particularly salient and/or influential cues to women's breastfeeding decisions would benefit intervention development. We explored this to some extent by looking separately at the eight items that did not load on to our two summary measures. While we did not find evidence for effects of the physical environment in these supplementary analyses, we did find some evidence for independent effects of the sociocultural environment on breastfeeding outcomes. Seeking support, having other parents to talk to and spending time with friends were all independently strongly associated (although not all positively) with breastfeeding outcomes, suggesting that these specific aspects of the sociocultural environment can influence infant feeding decisions without necessarily acting in concert with other aspects of local environmental quality. It could be that these particular aspects of environmental experience have more direct influences on breastfeeding, with for example mothers seeking support, or talking to friends and other parents *specifically* about infant feeding - while our summary measures instead represent broader (non-breastfeeding specific) barriers. Further work is needed to tease specific environmental influences apart as there may be little merit in providing a breastfeeding intervention in a neighbourhood where women will not use it because of other environmental problems.

2.5.5 Implications

With infant feeding back on the political agenda as a result of the recent Lancet breastfeeding series (Rollins et al., 2016; Victora et al., 2016), tackling the many barriers that prevent women from breastfeeding has become a priority. Recently, efforts to improve breastfeeding outcomes have shifted focus from individual women to larger societal issues (Unicef UK Baby Friendly Initiative, 2016). Evolutionary theory adds value by generating precise predictions and new lines of enquiry that may be missed elsewhere. The findings that emerge from such evolutionary studies are also important for policy makers as they may highlight aspects that policy makers can actually change. The environment can be modified to improve health outcomes with less onus on the individual (Nettle, 2009) and is therefore a useful avenue for improving breastfeeding. Our study has shown that there may be broader environmental barriers (environmental quality) behind the breastfeeding-specific social, cultural, economic, physical and practical barriers highlighted by UNICEF (Ashmore, 2016).

Furthermore, by focusing on differences in environmental quality we can draw attention towards core economic inequities and concentrate on the benefits to be yielded through structural change (Nettle, 2010b, p. 5). There is a historical tradition of placing blame on the individual when he/she becomes sick and the medicalisation of breastfeeding (Faircloth, 2010) has exacerbated feelings of pressure and guilt for new mothers (Earle, 2002; Fox et al., 2015; Hauck & Irurita, 2003). Breastfeeding is a particularly emotive process with women's sense of self-worth and value intrinsically linked to its success (Hufton & Raven, 2014; Thomson et al., 2014). As such, a shift from the individual towards the environment in infant feeding discourse, and indeed in breastfeeding interventions, would be helpful in improving the emotional wellbeing of mothers and in turn the health of their children. Improving the local environment will undoubtedly have knock-on positive consequences for the health of the rest of the neighbourhood too.

2.6 DECLARATIONS OF FUNDING

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3. ARE MOTHERS LESS LIKELY TO BREASTFEED IN HARSH ENVIRONMENTS? PHYSICAL ENVIRONMENTAL QUALITY AND BREASTFEEDING IN THE BORN IN BRADFORD STUDY (STUDY 2)

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Student	Laura J Brown
Principal Supervisor	Rebecca Sear
Thesis Title	Understanding socioeconomic disparities in breastfeeding in the UK: Exploring the role of environmental quality

If the Research Paper has previously been published please complete Section B, if not please move to Section C

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3.1 ABSTRACT

We use the UK's Born in Bradford study to investigate whether women in lower-quality environments are less likely to breastfeed. We use measures of physical environmental quality (water disinfectant by-products (DBPs), air pollution, passive cigarette smoke, and household condition) alongside socioeconomic indicators, to explore in detail how different exposures influence breastfeeding. Drawing on evolutionary life history theory, we predict that lower environmental quality will be associated with lower odds of initiating, and higher hazards of stopping, breastfeeding. As low physical environmental quality may increase the risk of adverse birth outcomes, which may in turn affect breastfeeding chances, we also test for mediation by gestational age, birthweight, baby's head circumference and abdominal circumference. Our sample is comprised of mothers who gave birth at the Bradford Royal Infirmary in West Yorkshire between March 2007 and December 2010 for whom breastfeeding initiation data was available. Analyses were stratified by the two largest ethnic groups: White British (n=3,951) and Pakistani-origin (n=4,411) mothers. After controlling for socioeconomic position, Pakistani-origin mothers had lower chances of initiating, and higher chances of stopping breastfeeding with increased water DBP exposure (e.g. OR for 0.03-0.61 vs <0.02μg/day dibromochloromethane exposure 0.70 [0.58-0.83], HR 1.16 [0.99-1.36]; greater air pollution exposure predicted lower chances of initiation for both ethnic groups (e.g. OR for 10μg/m³ increase in nitrogen dioxide 0.81 [0.66-0.99] for White British mothers and 0.79 [0.67-0.94] for Pakistani-origin mothers) but also a reduced hazard of stopping breastfeeding for White British mothers (HR 0.65 [0.52-0.80]); and exposure to household damp/mould predicted higher chances of breastfeeding initiation amongst White British mothers (OR 1.66 [1.11-2.47]). We found no evidence that physical environmental quality effects on breastfeeding were mediated through birth outcomes amongst Pakistani-origin mothers, and only weak evidence ($p<0.10$) amongst White British mothers (exposure to passive cigarette smoke was associated with having lower birthweight infants who were in turn less likely to be breastfed whereas greater air pollution exposure was associated with longer gestations and in turn reduced hazards of stopping breastfeeding). Overall, our findings suggest that there is differential susceptibility to environmental exposures according to ethnicity. Whilst the water DBP results for Pakistani-origin mothers and air pollution-initiation results for both ethnic groups support our hypothesis that mothers exhibit reduced breastfeeding

in poorer-quality environments, several physical environmental quality indicators showed null or positive associations with breastfeeding outcomes. We consider physiological explanations for our findings, and their implications for life history theory and public health policy.

Key words: breastfeeding, trihalomethanes, pollution, smoke, socioeconomic position, Born in Bradford

3.2 KEY MESSAGES

- The association between physical environment quality and breastfeeding varies by type of exposure, outcome and ethnicity.
- There is some evidence that water disinfectant by-products and air pollution reduce breastfeeding, particularly for initiating breastfeeding and for Pakistani-origin mothers, but some null and some positive associations between physical environmental quality and breastfeeding were also found.
- Evolutionary life history theory serves as a useful framework for understanding human reproductive behaviour. It emphasises the importance of environmental quality in predicting behaviours such as parental investment, and thereby shifts focus away from individual factors and towards modifiable aspects of the environment.

3.3 INTRODUCTION

There are many factors which impact a woman's infant feeding journey. Here, we contribute to the developing field of evolutionary public health by using evolutionary life history theory to inform an analysis of breastfeeding behaviour risk (Wells et al., 2017). Life history theory predicts that environmental quality may pattern reproductive behaviour and decision-making, because low-quality environments correlate with lower access to resources and higher morbidity and mortality risk (Dickins, Johns, & Chipman, 2012; Kaplan & Gangestad, 2012; Nettle, 2010b; Quinlan, 2007; Voland, 1998; but see Baldini, 2015). Under certain assumptions, this relatively high environmental risk is thought to trigger behavioural and physiological responses which prioritise having children relatively early, having more of them, and investing relatively less in each i.e.

favouring a quantity over quality reproductive strategy in order to ensure successful reproduction despite high mortality risk (Caudell & Quinlan, 2012; Nettle, 2010a). Empirical studies have consistently shown that women in harsher environments have earlier first births, more births, and a greater risk of preterm delivery and lower birthweight and/or smaller infants. This is the case in both cross-population (Bulley & Pepper, 2017; Caudell & Quinlan, 2012; Bobbi S. Low, Hazel, Parker, & Welch, 2008) and within-population studies, including high-income populations such as the UK, where overall mortality risk is relatively low but there is still considerable within-population variation in mortality and morbidity (Agyemang et al., 2009; Auger et al., 2012; Clemens & Dibben, 2017; Luo, Wilkins, & Kramer, 2006; Pearl et al., 2001; Schempf et al., 2009; Virgo & Sear, 2016).

There is less evidence that harsh environments are associated with post-natal parental investment, but reduced breastfeeding is potentially one mechanism which could have evolved to decrease parental investment in lower-quality environments; as well as being a mechanism through which women could achieve higher fertility in such environments (throughout most of human history, at least, when shortened breastfeeding durations would have been associated with shorter birth intervals) (Caudell & Quinlan, 2012; Chisholm, 1993; Nettle, 2010a; Pepper & Nettle, 2014c; Quinlan, 2007). Breastfeeding may be partly influenced by unconscious responses to environmental cues, in an evolved, (previously) adaptive response. In contemporary high-income contexts, breastfeeding is of course just one of several ways in which mothers can invest in their children and we make no judgement of women’s different infant feeding choices here. Many mothers who do not breastfeed opt to formula feed instead, which can also be considered as maternal investment, but in an economic rather than a physiological sense, especially for socioeconomically-disadvantaged mothers for whom formula incurs a higher financial cost (Raisler, 2000; UNICEF, 2002). There are also many other non-feeding related investments parents can make, like those made in other aspects of infant care such as protection and education (Shenk, 2011). Our study focuses on breastfeeding however, an important influence on maternal and infant health (Ip et al., 2007; Victora et al., 2016); we test the impact of physical environmental conditions thereby contributing a valuable hypothesis to public health interventions.

Human environments are both physical and social and it is important to account for both factors when understanding environmental influences on health and behaviour. In the UK, the link between the social environment, as measured by socioeconomic position (SEP), and breastfeeding is well-established (McAndrew et al., 2012). Disadvantaged women with lower incomes, lower status jobs and/or lower educational attainment are less likely to intend to breastfeed, less likely to initiate it and if they do, they tend to breastfeed for shorter durations. Current UK policy entitles women to 12 months of maternity leave with the first 6 weeks paid at average weekly earnings, then £145.18 per week thereafter (GOV.UK, 2019). The UK Equality Act 2010 defines treating a woman unfavourably because she is breastfeeding as discrimination (Maternity Action, 2014) but the law does not currently allow a simple straightforward right to breastfeeding breaks at work, although employers do have to consider health and safety issues (Health and Safety Executive, 2019; Maternity Action, 2018). With barriers to providing lactation breaks evident in large public sector organisations (Fraser, 2016), it is likely that the smaller and less formal organisations that more socioeconomically-disadvantaged mothers often work for, will be even less supportive in this regard (Heinig et al., 2006).

Socioeconomic position is not the only way that large societies are stratified. The UK is home to great diversity, with people of various ethnic backgrounds and immigration histories calling this country home (Office for National Statistics, 2012). Ethnicity and socioeconomic status can be intertwined, with some ethnic minorities also being socioeconomically disadvantaged. For example, ethnic minorities may be more likely to live in deprived areas of the UK than their White counterparts (McAndrew et al., 2012). Socioeconomic position and ethnicity do however impart different influences on breastfeeding, and socioeconomic position may have more of a beneficial effect in some ethnic groups than others. For example Kelly et al. found that higher income levels were associated with increased odds of initiating breastfeeding amongst White and Asian mothers, but that it had less of a consistent effect amongst Black mothers (2006). Ethnicity can be considered a proxy for differing immigration histories and cultural influences and as such is an important factor to explore in relationships between environmental conditions and breastfeeding outcomes. While socioeconomic position and ethnicity may capture women's social, cultural and economic constraints and opportunities, there are physical aspects of environmental quality which may also influence reproduction and parenting, either because they directly influence physiology, or because they act as cues to environmental quality to which women respond by changing their reproductive behaviour (not necessarily consciously).

By virtue of different environmental exposures, socioeconomic circumstances and cultural influences, the impact of physical environmental quality on breastfeeding is likely to vary between populations. Life history theory predicts that parental investment will be reduced in harsher environmental conditions and/or when resources are scarce. However, low- and middle-income countries generally have higher breastfeeding rates than high-income countries (Victora et al., 2016) even though the environments in these contexts are in many ways "harsher". Analyses focusing on pre-industrial societies have however shown that even in these harsher contexts, there is *within*-population variation in parental investment whereby breastfeeding tracks ecological stress, with mothers terminating breastfeeding sooner under conditions of warfare and famine and weaning showing a quadratic relationship with pathogen stress (Quinlan, 2007).

We have previously shown a positive association between environmental quality and breastfeeding in the UK, both when environmental quality was measured using aggregated data at Primary Care Trust level (Laura J Brown, 2014) and with individual data at the home, street and neighbourhood level (L.J. Brown & Sear, 2017). We looked at environmental effects on breastfeeding initiation and duration of any breastfeeding in the Millennium Cohort Study (L.J. Brown & Sear, 2017), using a broad definition of environmental quality encompassing both sociocultural and physical aspects, such as how supportive and friendly people were and whether there were signs of crime and antisocial behaviour; as well as the built environment and perceptions of cleanliness and general environmental pollution. We found that for every one-unit increase in objectively-assessed local environmental quality, mothers were 54% more likely to initiate breastfeeding (CI 1.23-1.92) and 14% less likely to stop breastfeeding (CI 0.77-0.97), even after controlling for socioeconomic position. We also found significant effect modification with more advantaged SEP having a 'buffering' effect, reducing the magnitude of the consequences of adverse environmental quality. Women from high-income households had relatively high breastfeeding initiation rates and those with high status jobs were more likely to maintain breastfeeding even in harsh environmental conditions. Here we focus more narrowly on physical aspects of the environment, such as water disinfectant by-products (DBPs) and air pollution, to test the prediction that a poor-quality (harsher) physical environment will negatively impact breastfeeding, alongside an assessment of the association between SEP and breastfeeding.

3.3.1 Physical environmental quality and breastfeeding: proximate mechanisms and ultimate perspectives

An integrative evolutionary approach requires both proximate explanations of how a behaviour works, and also an 'ultimate' explanation as to why it exists (Nettle, 2011). Ultimate explanations centre on fitness consequences of a behaviour, explain why it is favoured (or not) in certain contexts and address its evolutionary function (Scott-Phillips, Dickins, & West, 2011). So far we have proposed an ultimate explanation for reduced breastfeeding in lower quality environments: lower parental investment and higher fertility are adaptive in harsh environments. But what are the proximate (i.e. immediate physiological or behavioural) mechanisms which explain the relationship between harsh environments and breastfeeding? Physical aspects of the environment may directly influence maternal and child physiology, which then influences reproductive and parenting behaviours. We acknowledge that a complication is that breastfeeding is a dyadic process influenced by the infant too (Tully & Ball, 2013). There has been relatively little research explicitly linking environmental pollutant exposure with breastfeeding outcomes, but chemical compounds have been detected in breastmilk (Stefanidou, Maravelias, & Spiliopoulou, 2009), some of which are likely to have endocrine disrupting capabilities (Pedersen et al., 2013, p. 72). Hormonal disruption or toxicity can impact mammary gland development during pregnancy (Rosen-Carole et al., 2017) and also the lactation process itself. This is certainly the case for maternal smoking which has been shown to interfere with the milk ejection reflex, reduce milk output, alter the taste and composition of breastmilk, as well as suppress infant appetite and increase irritability (L. H. Amir, 2001). It is possible that exposure to passive cigarette smoke and other pollutants such as those from vehicle exhaust fumes, chlorinated water and damp and mould will have some of the same effects, albeit that the level of toxin exposure may be substantially less.

3.3.1.1 Adverse birth outcomes as a mediating factor

Physical aspects of the environment may also influence reproductive and parenting behaviours through indirect links. For example, an association between environmental pollutants and breastfeeding may be mediated by adverse birth outcomes. Evidence for the relationship between pollutants and adverse birth outcomes is mixed, possibly due to varying methodology, differing levels of exposure and misclassification (Poirier et al., 2015), though there does seem to be consensus that pollution can harm the developing foetus. Pollutant exposure may be linked with an increased risk of spontaneous abortion and stillbirth (Faiz et al., 2012; Waller, Swan, Delorenze, & Hopkins, 1998), but it may also increase the risk of prematurity or having a low birth weight or small for gestational age baby (Dadvand et al., 2013; Nieuwenhuijsen, Dadvand, Grellier, Martinez, & Vrijheid, 2013).

Prematurity and low birthweight can affect an infant's ability to suckle, swallow and breathe, increasing vulnerability to feeding problems (Wambach & Riordan, 2016). Affected babies are also more likely to be separated from their mothers at birth, for example by being moved to incubators, depriving dyads of skin-to-skin and making establishing breastfeeding more difficult. In addition to these proximate explanations, evolutionary theory predicts that parental investment is lower when offspring chances of reproducing themselves appear diminished (Heijkoop, 2010; Mann, 1995). Therefore an ultimate perspective predicts that in order to adjust lactational investment optimally, mothers must evaluate infant health status and reproductive value (not necessarily consciously). Several studies have provided support for this hypothesis, for example: mothers of twins have been shown to bias investment towards the healthier twin (Mann, 1995); interbirth intervals are shorter following the birth of a child with a long-term health problem (Waynforth, 2015); and mothers of low birthweight infants have been shown to wean earlier (Bereczkei, 2001).

3.3.2 Our predictions

The aim of this study is to test whether mothers are less likely to breastfeed in harsh environments, a prediction derived from the evolutionary framework of life history theory. We look specifically at one region in North England to answer this question and focus on small-scale within-population heterogeneity in physical environmental quality. In particular we hypothesise that worse household condition (i.e. having no central heating and being exposed to damp/mould) and greater exposure to water disinfectant by-products, air pollution, and passive cigarette smoke will negatively impact women's breastfeeding chances by reducing their odds of initiating breastfeeding and increasing their hazards of stopping breastfeeding. We further hypothesise that these aspects of the physical environment may also have indirect effects on the same breastfeeding outcomes through potentially harming foetal development resulting in mothers having smaller neonates whom they are less likely to breastfeed.

3.4 METHODS

3.4.1 Dataset

The Born in Bradford cohort study (BiB) follows the health and wellbeing of over 13,500 children born at the Bradford Royal Infirmary, West Yorkshire, England between March 2007 and December 2010. Pregnant women were primarily recruited at 26-28 weeks gestation when attending the hospital for routine tests. There have been several waves of data collection to date. Of relevance to this study, a baseline interviewer-administered questionnaire was completed shortly after recruitment which captured sociodemographic data; details of delivery, birthweight and antenatal information were obtained from maternity and radiology information systems; babies had abdominal and head circumferences measured before discharge; and breastfeeding information was recorded during health worker visits and linked back to the main dataset. Further follow-up occurred for two sub-cohorts – BiB1000 and ALLIN (ALLergy and INfection) – over the first 4 and 2 years of life respectively, from which we obtained information on breastfeeding duration. An additional sub-sample took part in the MeDALL (MEchanism of the Development of ALLergy) study, for whom we have additional information on household condition and breastfeeding at age 4 years. We use air pollution measures collected as part of the multi-site European Study of Cohorts for Air Pollution Effects (ESCAPE) project (Pedersen et al., 2013). Routine water quality monitoring data were provided by Yorkshire Water for the eight water supply zones covering the study area from January 2006 to March 2011 and exposure levels were derived by Mireille Toledano and Imperial College of Science Technology and Medicine (R. B. Smith et al., 2016). More details on the cohort, sub-cohorts and data collection is available elsewhere (R. B. Smith et al., 2016; Wright et al., 2013).

We only included mothers with live births (excluding 72 mothers), and where mothers had twins or triplets, we randomly chose one child for inclusion (excluding 182 babies). For mothers with repeated pregnancies during the data collection period (2007-2010), we randomly selected one pregnancy (excluding a further 1,286 babies). These restrictions to one mother-one child data points were to ensure each mother just contributed one case to the dataset to avoid issues of clustering at the mother level. Our sample includes mothers of varying parity, not just first time mothers as some women will have given birth prior to inclusion in the study. This gave us an initial maximum usable sample size of 12,318 mother-infant dyads.

3.4.2 Variables

3.4.2.1 Ethnicity

Given that breastfeeding practices and environmental exposure may differ by ethnicity (a proxy for differing immigration histories and cultural influences), we present stratified results, focusing on the two main ethnic groups in Bradford - White British (n=4,031) and Pakistani-origin (n=4,448) mothers. We also present model results for the total sample), but do not attempt to interpret results for the rest of the sample, since it comprised a heterogeneous “other” ethnicity category (n=1,541) and women who did not provide their ethnicity (n=2,298).

3.4.2.2 Breastfeeding outcomes

We used two outcomes: 1) breastfeeding initiation and 2) duration of any (rather than exclusive) breastfeeding. We combined breastfeeding initiation data from health visitor records and sub-cohort follow-up. This gave us initiation data for 98% of the women in our sample (n=12,087, missing=231).

3,737 women took part in at least one of the sub-cohort surveys in which duration questions were asked, of which 80% had initiated breastfeeding (n=2,979). We were able to derive duration for 95% of these women (n=2,827). Duration was replaced with the baby's age for the 407 mothers who were still breastfeeding at the time of their last survey (167 of whom were White British and 159 of whom were Pakistani-origin). Where mothers stopped breastfeeding between surveys, duration was coded as the age of the child in the last survey where breastfeeding was recorded as still happening (likely underestimating durations for some mothers). Mothers who initiated breastfeeding but who recorded duration as 0 days were recoded as half a day (0.02months) to acknowledge that some transfer of breastmilk may have occurred and to differentiate these mothers from those who did not attempt breastfeeding at all.

3.4.2.3 Physical environmental quality indicators

All measures were coded so that higher values represented greater exposure and poorer environmental quality. Where possible we have used data on exposure during pregnancy but have had to use later exposure as proxies for some indicators.

3.4.2.3.1 Water disinfectant by-products

We used five water DBP indicators: total trihalomethanes, brominated trihalomethanes (subdivided into bromodichloromethane and dibromochloromethane) and chloroform. Modelled trihalomethane concentrations encompassing residential (and workplace, if relevant) address were assigned and time-weighted average concentrations were calculated for each mother in the study. The time-weighting was based on the proportion of the whole pregnancy falling into each month. These time-weighted average concentrations were then adjusted for individual water use including consumption, showering, bathing and swimming (R. B. Smith et al., 2016) to create a personalised measure of whole pregnancy average integrated uptake (µg/day). All five indicators had positively skewed distributions and so we created tertiles of exposure based on the full sample of women.

3.4.2.3.2 Air pollution

As part of the ESCAPE project, 20 European study areas collected measurements of particulate matter (e.g. $PM_{2.5}$ and PM_{10}) and nitrogen oxides (NO_2 and NO_x). We used nitrogen oxide measures as our indicators of air pollution, as Bradford was one of the 16 ESCAPE sites that did not collect particulate matter measures (Beelen et al., 2013).

In addition, the evidence is less consistent for links between nitrogen oxides and infant health outcomes (Shah & Balkhair, 2011), and as such our paper makes an important contribution to the evidence base. Furthermore, Bradford is one of the UK's nitrogen oxide pollution hotspots (Google My Maps, 2019): nitrogen oxide levels were relatively high in Bradford between 2007 and 2010, surpassing the annual average air quality objective level of 40µg/m^3 (Maybury, 2016) and levels have remained high in recent years (Department for Environment Food and Rural Affairs, 2019). As part of the ESCAPE project, exposure estimates were personalised with land use regression models to take into account each mother's proximity to traffic and buildings and their load and density at different time points during pregnancy (Beelen et al., 2013). We selected whole pregnancy average exposure levels of nitrogen oxides (20µg/m^3) and nitrogen dioxide (10µg/m^3) for use in the present study. The nitrogen oxides indicator encompasses nitrogen dioxide as well as nitric oxide. We used continuous indicators in the main models (but created tertiles when testing for interactions with ethnicity) as both measures were normally distributed.

3.4.2.3.3 Passive cigarette smoke

Mothers were asked in the baseline questionnaire if they were exposed to cigarette smoke at work or at home and we collapsed *Yes* and *Less than an hour* into *Yes* to make this a binary variable.

3.4.2.3.4 Household condition

We used two binary variables for household condition based on maternal reporting of damp and/or mould and lack of central heating, derived from the ALLIN and MeDALL sub-cohorts at 12 months, 24 months and/or 4 years.

3.4.2.4 Socioeconomic position (SEP)

A wide range of socioeconomic position (SEP) indicators have been shown to be associated with both adverse birth outcomes (Erickson & Arbour, 2014) and breastfeeding (McAndrew et al., 2012). As a proxy for individual resources and to some extent, social environmental quality, we wanted to capture the multifactorial nature of socioeconomic position so used five indicator variables (all taken from the baseline questionnaire) to construct a latent variable: mother's education, her partner's occupation, financial difficulties, means-tested benefits and food insecurity. This allocated everyone a disadvantage score which we then standardised to aid interpretation of model results. We also included the IMD (Index of Multiple Deprivation) 2010 score (McLennan et al., 2011) as a measure of neighbourhood deprivation in descriptive analyses. Higher values represented more disadvantage for both SEP measures.

3.4.2.5 Covariates

We adjusted for key maternal and infant characteristics known to influence breastfeeding and/or birth outcomes: maternal age, immigration status, smoking during pregnancy, BMI, parity, infant sex, singleton/multiple birth and cohabitation status. This reduced our maximum sample size down to 8,993 mothers (3,615 White British and 3,982 Pakistani-origin).

3.4.2.6 Birth outcomes

Birthweight in kilograms, head and abdominal circumferences in centimetres and gestational age in weeks were used as continuous measures in our mediation models.

3.4.3 Statistical Methods

We first explored the data by using t-tests and chi-squared tests to compare White British and Pakistani-origin mothers in terms of their sociodemographic characteristics, birth outcomes, environmental exposures and breastfeeding outcomes. We also compared those with missing initiation data to the rest of the sample in the same way. We assessed associations between physical environmental quality indicators using polychoric, polyserial and Pearson's correlations as appropriate. Unadjusted associations between our two measures of SEP (socioeconomic disadvantage and neighbourhood deprivation) and physical environmental quality were assessed using linear and logistic regression models as appropriate. To test our hypothesis about the association between physical environmental quality and breastfeeding, we ran separate statistical models for each of the ten physical environmental quality indicators and breastfeeding outcomes i.e. only including one indicator at a time. Our first set of models adjusted for the key maternal and infant covariates listed above, and our second set of models additionally adjusted for the standardised socioeconomic disadvantage score. This allowed us to see whether any association persisted above and beyond the effect of individual socioeconomic position (we also ran models to test the association between socioeconomic position and breastfeeding outcomes). Logistic regression models were used to assess relationships with breastfeeding initiation, whilst we used event history analysis to take account of the right-censored breastfeeding duration data (using the Weibull distribution to reflect the diminishing probability of breastfeeding over time). Breastfeeding duration results are therefore presented as hazard ratios reflecting the risk of stopping breastfeeding for different environmental exposures. . As well as running analyses separately by ethnicity, we also ran the two sets of models on White British and Pakistani-origin mothers combined, adding in an *environmental quality X ethnicity* interaction to test for ethnic differences in the effect of physical environmental quality on breastfeeding outcomes. We plotted predicted probabilities of initiating and maintaining breastfeeding based on these interaction models to visually compare associations amongst the two groups. The probability of maintaining breastfeeding is presented as a survival curve where the "failure" variable is stopping breastfeeding and "surviving" is maintaining breastfeeding at a given time point.

We tested for mediation using structural equation modelling adding pathways through birth outcomes to the fully adjusted models and examining indirect effects. We ran models for birthweight, head circumference and abdominal circumference (all simultaneously adjusted for gestational age) and for gestational age separately (with all environmental quality indicators treated as continuous to allow for estimation of indirect effects).

We conducted complete case analyses and so sample sizes varied depending on the outcome and indicator included in the model.

3.4.4 Ethics

BiB and its sub-studies have been approved by the Bradford Research Ethics Committee (Wright et al., 2013). The current study received ethics approval from the London School of Hygiene & Tropical Medicine's Research Ethics Committee (9398-01).

3.5 RESULTS

3.5.1 Sample characteristics

White British and Pakistani-origin mothers significantly differed in most characteristics (Table 3.1). Pakistani-origin mothers had higher levels of initiation (57% versus 42%) but duration was similar at 8-9 months for both groups. Pakistani-origin mothers had lower exposure to water DBPs and were less likely to be exposed to passive smoke, but had higher exposure to air pollution. There were no ethnic differences in either indicator of household condition. Pakistani-origin mothers had higher SEP scores indicating greater socioeconomic disadvantage. On average, they had less education, greater neighbourhood deprivation, were more likely to be on means-tested benefits and experience financial difficulties, but were less likely to experience food insecurity. Pakistani-origin women's partners were less likely to be non-manual workers and more likely to be manual workers or self-employed compared to White British women's partners. The immigration statuses of the two groups significantly varied; the majority of White British mothers were born in the UK whilst almost all of the Pakistani-origin mothers were first or second generation immigrants. Pakistani-origin mothers had lower BMIs and higher parity but were just as likely to have a female infant or multiple birth. Fewer Pakistani-origin mothers were living without a partner. In terms of birth outcomes, Pakistani-origin infants tended to be born earlier and were lighter, with smaller head and abdominal circumferences.

Although mothers with missing initiation data (n=231) significantly differed from the rest of the sample in terms of some of the environmental exposures, SEP and other sociodemographic factors (Table 3.1), their small numbers means that these differences are unlikely to affect the interpretation of our results.

3.5.2 Associations between physical environmental quality indicators

In our descriptive analyses, several environmental quality indicators were positively associated with one another in both ethnic groups, although the correlations varied in strength and significance. Focusing just on significant correlations (at $p<0.05$), the strongest positive correlations were between the different water DBPs ($r=0.914$ to 1) and between the different air pollution indicators (r=0.820 and 0.826). Passive smoke exposure was more weakly positively associated with water DBPs in both ethnic groups (r=0.077 to 0.153), and also with air pollution (r=0.057 and 0.103) and damp/mould amongst White British mothers (r=0.125). Household condition only correlated with other environmental quality exposures amongst Pakistani-origin mothers; both indicators were weakly positively correlated with exposure to nitrogen dioxide (r=0.184 and r=0.132) and having no central heating was also weakly positively correlated with nitrogen oxide exposure (r=0.242). However, several water DBPs were *negatively*, albeit weakly, associated with air pollution amongst Pakistani-origin mothers (r=-0.034 to -0.079). These correlations suggest that exposures broadly cluster together, perhaps indicating a 'harsh' physical environment, particularly for White British mothers, but the separate indicators measure slightly different aspects of the environment. Correlations between the environmental quality indicators are shown in Table B.1 in Appendix B.

3.5.3 Socioeconomic position and physical environmental quality

Disadvantaged socioeconomic position (SEP) was generally associated with poorer physical environmental quality, with for example, both greater individual socioeconomic disadvantage and neighbourhood deprivation (IMD) being positively associated with greater air pollution exposure (Table 3.2). There were some differences by ethnicity for the other exposures though. Most notably, although White British mothers who were more socioeconomically disadvantaged and who lived in more deprived neighbourhoods had higher levels of water DBP exposure, there was no association amongst Pakistani-origin mothers (except for between IMD and dibromochloromethane exposure). Passive smoke exposure was positively associated with socioeconomic disadvantage in both ethnic groups, but with neighbourhood deprivation only amongst White British mothers. Damp/mould exposure was more likely for socioeconomically disadvantaged White British mothers and for mothers of either ethnicity living in more deprived neighbourhoods. Only Pakistani-origin mothers living in more deprived neighbourhoods were less likely to have access to central heating. This suggests that a lower quality physical environment is broadly associated with a lower quality socioeconomic environment, though again this relationship is stronger for White British mothers.

3.5.4 Socioeconomic position and breastfeeding

The first lines of Tables 3.3 and 3.4 show the relationship between socioeconomic position and breastfeeding initiation and the hazard of stopping breastfeeding after controlling for maternal and infant characteristics. Although not shown for brevity, the SEP-breastfeeding associations in the M2 environmental quality models were very similar to the M1 associations presented, suggesting that socioeconomic disadvantage influences breastfeeding separately from these aspects of the environment.

3.5.4.1 Breastfeeding initiation

More socioeconomically disadvantaged mothers had lower odds of initiating breastfeeding. The odds of initiating breastfeeding decreased by 23% and 20% for each standard deviation increase in socioeconomic disadvantage for White British and Pakistani-origin mothers, respectively.

3.5.4.2 Breastfeeding duration

Mothers with greater socioeconomic disadvantage had increased hazards of stopping breastfeeding. The hazard of stopping breastfeeding increased by 11% and 13% for each standard deviation increase in socioeconomic disadvantage for White British and Pakistani-origin mothers respectively.

3.5.5 Physical environmental quality and breastfeeding

The remaining rows of Tables 3.3 and 3.4 present results of our analyses of the relationships between the environmental quality indicators and breastfeeding initiation and duration (hazard of stopping). M1 models are adjusted for maternal and infant characteristics and M2 models are additionally adjusted for SEP. Note that each row in the tables refers to a separate model, as we ran individual models for each environmental quality indicator. The last column shows the results of the significance tests for the interactions between ethnic group and environmental quality from models controlling for maternal and infant characteristics and SEP and including White British and Pakistani-origin mothers, but excluding other ethnicities. The corresponding predicted probabilities based are presented in Figure 3.1.

3.5.5.1 Breastfeeding initiation

Results of our initiation analyses broadly suggest support for our predictions, with the exception of the damp/mould indicator, though not all environmental indicators were significantly associated with initiation and there were some differences between ethnic groups.

3.5.5.1.1 Water DBPs

Whilst there were no significant relationships between DBPs and initiation amongst White British mothers, all DBP measures were significant negative predictors amongst Pakistani-origin mothers. All five DBP measures showed a dose-response relationship whereby Pakistani-origin mothers in the mid- and high-exposure tertiles both had reduced odds compared to the low-exposure tertiles. For example, Pakistani-origin mothers exposed to mid-levels of dibromochloromethane (0.02-0.03μg/day) were 28% less likely to initiate breastfeeding compared to those exposed to low levels (<0.02μg/day), whilst those exposed to high levels (0.03-0.61μg/day) were 30% less likely. Adjusting for SEP had little effect on the associations between water DBPs and breastfeeding amongst Pakistani-origin mothers; adjusted effect sizes ranged between a 22-31% reduction in the odds of initiation. The significant interaction between dibromochloromethane exposure and ethnicity (p=0.018) is shown in Figure 3.1a: Pakistani-origin mothers with low exposure have a 55% probability of initiating breastfeeding whilst those with mid and high exposure have similarly lower chances at just 47%. White British mothers show a U-shaped relationship, with the lowest probability occurring at mid-exposure levels (47%), and low and high levels conferring probabilities of 50% and 52%, respectively.

3.5.5.1.2 Air pollution

Whilst both air pollution measures were significantly negatively associated with breastfeeding initiation amongst Pakistani-origin mothers, only nitrogen dioxide exposure showed a significant association amongst White British mothers. These associations persisted after adjusting for SEP, with significant effect sizes varying from a 19-27% reduction in odds of initiation. Ethnicity did not interact with air pollution to predict breastfeeding initiation (Figure 3.1c).

3.5.5.1.3 Passive cigarette smoke

Passive smoke exposure was not significantly associated with breastfeeding initiation, although relationships were in the predicted direction, with exposure to smoke at work or home conferring lower odds in both ethnic groups (Figure 3.1e).

3.5.5.1.4 Household condition

Central heating access showed no significant association in either group, although relationships were all in the predicted direction, whereby no access conferred lower odds of initiating breastfeeding (Figure 3.1g). Contrary to our predictions, damp/mould exposure showed a positive association with initiation in both groups, though this relationship was only significant in White British mothers, and became stronger once SEP was controlled for, with exposed White British mothers being 66% more likely to initiate breastfeeding than those with no damp/mould exposure (Figure 3.1i).

3.5.5.2 Breastfeeding duration

In contrast to the breastfeeding initiation results, results for breastfeeding duration (hazard of stopping breastfeeding) were more mixed and did not offer strong support for our predictions.

3.5.5.2.1 Water DBPs

Water DBP exposure did not significantly predict hazards of stopping breastfeeding amongst White British mothers and associations were mostly going against the predicted direction (with greater exposure predicting *reduced* hazards of stopping breastfeeding). Water DBP associations were however in the predicted direction for Pakistani-origin mothers, but only dibromochloromethane was a significant predictor of the hazard of stopping breastfeeding and only at mid, not high, exposure levels. The effect became marginally stronger after controlling for SEP, with Pakistani-origin mothers exposed to 0.02-0.03µg/day of dibromochloromethane having a 21% higher hazard of stopping compared to those with low exposure (<0.02µg/day). These results hint at the predicted association between higher water DBP exposure and increased hazards of stopping breastfeeding in Pakistani-origin mothers only, and suggest that dibromochloromethane may be a particular chemical of interest. Although none of the water DBPs interacted with ethnicity to predict breastfeeding duration, Figure 3.1b illustrates the differential impact of exposure on the two main ethnic groups clearly. Pakistani-origin mothers with high exposure levels have lower probabilities of breastfeeding than those with low levels from about 1 month onwards, whilst the converse is true for White British mothers.

3.5.5.2.2 Air pollution

Contrary to our predictions, greater air pollution exposure was associated with a significant *reduction* in the hazard of stopping breastfeeding amongst White British mothers Nitrogen dioxide exposure showed the same direction of association amongst Pakistani-origin mothers, albeit non-significantly. Effect sizes also increased after controlling for SEP, with each 20μg/m³ increase of nitrogen oxides and each 10μg/m³ increase of nitrogen dioxide conferring a 23% and 35% reduction in the hazard of stopping breastfeeding, respectively. The interaction between ethnicity and nitrogen dioxide exposure (p=0.034) is clear in Figure 3.1d. The survival curve for nitrogen dioxide exposure shows that there while there was no difference in the probability of maintaining breastfeeding according to exposure level for Pakistani-origin mothers, White British mothers exposed to high levels of nitrogen dioxide (2.29-3.10 10μg/m³) had much higher chances of maintaining breastfeeding than those exposed to low levels (<1.94 10μg/m³), particularly after the first month or so. For example, White British mothers with high levels of nitrogen dioxide exposure have a 60% chance of breastfeeding until 6 months whereas those with low levels of exposure have just a 45% chance (Figure 3.1d).

3.5.5.2.3 Passive cigarette smoke

Passive smoke exposure did not significantly predict the hazard of stopping breastfeeding, whether or not SEP was controlled for, although associations were in the predicted direction in both ethnic groups with mothers exposed to smoke at work or at home having greater hazards of stopping breastfeeding than those unexposed. We found no significant interaction between ethnicity and passive smoke but the corresponding survival curve suggests that smoke exposure had more of a detrimental impact on maintaining breastfeeding for Pakistani-origin mothers than White British mothers (Figure 3.1f).

3.5.5.2.4 Household condition

Neither of the household condition indicators significantly predicted the hazard of stopping breastfeeding, before or after controlling for SEP. Relationships for central heating were in the opposite direction to that predicted with mothers without household heating having *lower* hazards of stopping breastfeeding compared to those with heating in both ethnic groups Household damp/mould exposure was also non-significantly associated with a *reduced* hazard of stopping breastfeeding in the models controlling for SEP. Neither household indicator significantly interacted with ethnicity but the survival curves in Figures 3.1h and 3.1j suggest that worse household condition appears to confer higher probabilities of maintaining breastfeeding amongst the White British mothers only.

3.5.5.3 Mediation by birth outcomes

We found some weak evidence for mediation amongst White British mothers, with indirect effects only significant at the 10% level, but no evidence for mediation amongst Pakistani-origin mothers.

Although there was no direct effect on breastfeeding, our mediation analyses showed that amongst White British mothers, passive smoke exposure had an indirect effect on breastfeeding initiation through birthweight: mothers exposed to passive cigarette smoke at home or at work had lower birthweight infants who were in turn less likely to be breastfed. Whilst this indirect effect was in the predicted direction, greater air pollution exposure (as indexed by both nitrogen oxides and nitrogen dioxides) was associated with *longer* gestations and in turn reduced hazards of stopping breastfeeding (i.e. longer durations), which goes against our prediction that increased exposure leads to smaller neonates and reduced breastfeeding.

Table 3.1: Characteristics of study population

	Total (n=12,318)									
	Mothers with initiation data (n=12,087)							Mothers missing initiation data (n=231)		
			Main ethnic groups							
	All ethnic groups (n=12,087)		White British mothers (n=3,951)		Pakistani-origin mothers (n=4,411)		P-value [b]	All ethnicities		P-value [c]
	n	n(%) or mean ± SD	n	n(%) or mean ± SD	n	n(%) or mean ± SD		n	n(%) or mean ± SD	
Breastfeeding										
Initiation	12,087	5,982 (49.49%)	3,951	1,645 (41.64%)	4,411	2,507 (56.84%)	**<0.001**	.	.	1.365
Duration (months) [a]	2,827	8.84 ± 8.96	902	8.21 ± 9.09	1,437	8.63 ± 8.86	0.271	.	.	
Physical environmental quality										
Water disinfectant by-products										
Total trihalomethanes	9,714	1.85 ± 1.63	3,863	2.27 ± 1.97	4,341	1.50 ± 1.21	**<0.001**	135	2.05 ± 1.92	0.145
<1.05µg/day		3,244 (33.40%)		917 (23.74%)		1,850 (42.62%)	**<0.001**		39 (28.89%)	0.310
1.05-1.82µg/day		3,240 (33.35%)		1,228 (31.79%)		1,470 (33.86%)			43 (31.85%)	
1.82-23.96µg/day		3,230 (33.25%)		1,718 (44.47%)		1,021 (23.52%)			53 (39.26%)	
Brominated trihalomethanes	9,714	0.25 ± 0.21	3,863	0.30 ± 0.24	4,341	0.20 ± 0.17	**<0.001**	135	0.29 ± 0.27	**0.016**
<0.14µg/day		3,244 (33.40%)		841 (21.77%)		1,938 (44.64%)	**<0.001**		39 (28.89%)	**0.036**
0.14-0.26µg/day		3,246 (33.42%)		1,278 (33.08%)		1,415 (32.60%)			37 (27.41%)	
0.26-3.34µg/day		3,224 (33.19%)		1,744 (45.15%)		988 (22.76%)			59 (43.70%)	
Bromodichloromethane	9,714	0.20 ± 0.16	3,863	0.24 ± 0.18	4,341	0.16 ± 0.13	**<0.001**	135	0.23 ± 0.21	**0.014**
<0.12µg/day		3,244 (33.40%)		852 (22.06%)		1,929 (44.44%)	**<0.001**		39 (28.89%)	***0.057***
0.12-0.21µg/day		3,245 (33.41%)		1,285 (33.26%)		1,407 (32.41%)			38 (28.15%)	
0.21-2.61µg/day		3,225 (33.20%)		1,726 (44.68%)		1,005 (23.15%)			58 (42.96%)	
Dibromochloromethane	9,714	0.03 ± 0.03	3,863	0.04 ± 0.04	4,341	0.02 ± 0.02	**<0.001**	135	0.04 ± 0.04	***0.075***
<0.02µg/day		3,245 (33.41%)		900 (23.30%)		1,862 (42.89%)	**<0.001**		38 (28.15%)	***0.057***
0.02-0.03µg/day		3,244 (33.40%)		1,215 (31.45%)		1,500 (34.55%)			39 (28.89%)	
0.03-0.61µg/day		3,225 (33.20%)		1,748 (45.25%)		979 (22.55%)			58 (42.96%)	
Chloroform	9,714	1.60 ± 1.44	3,863	1.96 ± 1.75	4,341	1.29 ± 1.05	**<0.001**	135	1.77 ± 1.67	0.191
<0.91µg/day		3,243 (33.38%)		933 (24.15%)		1,831 (42.18%)	**<0.001**		40 (29.63%)	0.332
0.91-1.56µg/day		3,241 (33.36%)		1,216 (31.48%)		1,484 (34.19%)			42 (31.11%)	
1.56-20.94µg/day		3,230 (33.25%)		1,714 (44.37%)		1,026 (23.64%)			53 (39.26%)	

Air pollution										
Nitrogen oxides (20µg/m³)	9,629	1.80 ± 0.42	3,809	1.67 ± 0.38	4,313	1.91 ± 0.41	**<0.001**	128	1.80 ± 0.43	0.944
<1.60µg/m³		3,215 (33.39%)		1,754 (46.05%)		979 (22.70%)	**<0.001**		38 (29.69%)	0.374
1.60-1.95µg/m³		3,212 (33.36%)		1,308 (34.34%)		1,432 (33.20%)			40 (31.25%)	
1.95-3.81µg/m³		3,202 (33.25%)		747 (19.61%)		1,902 (44.10%)			50 (39.06%)	
Nitrogen dioxide (10µg/m³)	9,629	2.14 ± 0.39	3,809	2.01 ± 0.36	4,313	2.22 ± 0.38	**<0.001**	128	2.14 ± 0.40	0.841
<1.94µg/m³		3,213 (33.37%)		1,748 (45.89%)		1,017 (23.58%)	**<0.001**		40 (31.25%)	0.880
1.94-2.29µg/m³		3,208 (33.32%)		1,299 (34.10%)		1,448 (33.57%)			44 (34.38%)	
2.29-3.81µg/m³		3,208 (33.32%)		762 (20.01%)		1,848 (42.85%)			44 (34.38%)	
Passive cigarette smoke	9,839	3,169 (32.21%)	3,936	1,697 (43.11%)	4,377	1,064 (24.31%)	**<0.001**	140	61 (43.57%)	**0.004**
Household condition										
No central heating	2,198	123 (5.60%)	834	41 (4.92%)	1,046	58 (5.54%)	0.544	.	.	
Damp and/or mould	2,932	598 (20.40%)	1,013	211 (20.83%)	1,519	304 (20.01%)	0.617	.	.	
Socioeconomic position										
Socioeconomic disadvantage [d]	12,087	-0.003 ± 0.999	3,951	-0.057 ± 1.146	4,411	0.146 ± 1.036	**<0.001**	231	0.160 ± 1.027	**0.014**
Food insecure	1,186	249 (20.99%)	443	128 (28.89%)	564	73 (12.94%)	**<0.001**	.	.	
Financial difficulties	10,022	779 (7.77%)	3,936	271 (6.88%)	4,383	345 (7.88%)	**0.027**	174	18 (10.34%)	0.376
Means tested benefits	9,863	3,884 (39.38%)	3,936	1,431 (36.36%)	4,398	2,005 (45.59%)	**<0.001**	139	64 (46.04%)	0.110
Partner's employment status	9,369		3,960		4,214		**<0.001**	129		**0.037**
Employed-Non-Manual		3,831 (40.89%)		1,892 (51.27%)		1,307 (31.02%)			44 (34.11%)	
Employed-Manual		3,220 (34.37%)		1,028 (27.86%)		1,721 (40.84%)			43 (33.33%)	
Self-employed		1,394 (14.88%)		376 (10.19%)		835 (19.81%)			19 (14.73%)	
Student		166 (1.77%)		53 (1.44%)		53 (1.26%)			3 (2.33%)	
Unemployed		758 (8.09%)		341 (9.24%)		298 (7.07%)			20 (15.50%)	
Education: <5 GCSE equivalent	9,266	2,127 (22.95%)	3,556	766 (21.54%)	4,198	1,133 (26.99%)	**<0.001**	160	62 (38.75%)	**<0.001**
Neighbourhood deprivation (IMD) [e]	9,895	42.09 ± 17.81	3,949	36.25 ± 19.08	4,410	46.56 ± 14.79	**<0.001**	143	41.80 ± 18.31	0.843
Ethnicity	9,879		3,951		4,410			141		**<0.001**
White British		3,951 (39.99%)		3,951 (100.00%)		0 (0.00%)			80 (56.74%)	
Pakistani-origin		4,411 (44.65%)		0 (0.00%)		4,411 (100.00%)			37 (26.24%)	
Other		1,517 (15.36%)		0 (0.00%)		0 (0.00%)			24 (17.02%)	

Covariates										
Immigration status	12,050		3,924		4,409			231		**<0.001**
Born in the UK and both parents born in the UK		3,893 (32.31%)		3,746 (95.46%)		25 (0.57%)	**<0.001**		82 (35.50%)	
2nd generation (at least one parent born outside UK)		2,378 (19.73%)		112 (2.85%)		1,850 (41.96%)			24 (10.39%)	
1st generation (arrived to UK as a child)		842 (6.99%)		46 (1.17%)		619 (14.04%)			7 (3.03%)	
1st generation (arrived to UK as an adult)		4,937 (40.97%)		20 (0.51%)		1,915 (43.43%)			118 (51.08%)	
Age (years)	9,898	27.31 ± 5.63	3,951	26.67 ± 6.08	4,411	27.70 ± 5.21	**<0.001**	143	26.48 ± 6.48	***0.078***
BMI	9,399	25.97 ± 5.68	3,744	26.67 ± 5.97	4,188	25.56 ± 5.42	**<0.001**	131	26.27 ± 5.55	0.548
Smoked during pregnancy	9,811	1,644 (16.64%)	3,948	1,330 (33.69%)	4,400	153 (3.48%)	**<0.001**	141	44 (31.21%)	**<0.001**
Parity	11,381	1.08 ± 1.29	3,807	0.77 ± 1.03	4,199	1.37 ± 1.42	**<0.001**	181	1.13 ± 1.55	0.656
0		4,979 (43.75%)		1,996 (52.43%)		1,521 (36.22%)	**<0.001**		87 (48.07%)	**0.002**
1		3,000 (26.36%)		1,092 (28.68%)		996 (23.72%)			45 (24.86%)	
2		1,850 (16.26%)		465 (12.21%)		826 (19.67%)			23 (12.71%)	
3		930 (8.17%)		158 (4.15%)		518 (12.34%)			7 (3.87%)	
4		397 (3.49%)		64 (1.68%)		211 (5.03%)			9 (4.97%)	
5+		225 (1.98%)		32 (0.84%)		127 (3.02%)			10 (5.52%)	
Female infant	11,830	5,731 (48.44%)	3,942	1,904 (48.30%)	4,396	2,142 (48.73%)	0.698	191	90 (47.12%)	0.717
Twins or triplets	11,831	149 (1.26%)	3,942	53 (1.34%)	4,396	66 (1.50%)	0.558	191	2 (1.05%)	0.950
Not living with partner	9,891	1,664 (16.82%)	3,946	1,128 (28.59%)	4,404	305 (6.93%)	**<0.001**	141	40 (28.37%)	**<0.001**
Birth outcomes										
Gestational age (weeks)	11,831	39.13 ± 1.79	3,942	39.26 ± 1.84	4,396	39.07 ± 1.73	**<0.001**	191	37.76 ± 3.81	**<0.001**
Birthweight (kgs)	11,830	3.22 ± 0.55	3,941	3.35 ± 0.56	4,396	3.13 ± 0.53	**<0.001**	191	2.95 ± 0.86	**<0.001**
Head circumference (cms)	10,962	34.22 ± 1.62	3,632	34.52 ± 1.60	4,061	34.01 ± 1.58	**<0.001**	138	34.01 ± 2.33	0.128
Abdominal circumference (cms)	10,409	31.21 ± 2.66	3,447	31.95 ± 2.63	3,866	30.65 ± 2.59	**<0.001**	128	31.53 ± 2.51	0.173

[a] Breastfeeding duration questions only asked of those in sub-cohorts; 117 women with "Don't knows" and 35 provided no answers to duration questions. [b] P-values for t-tests and X^2 comparing White British and Pakistani-origin mothers. [c] P-values for t-tests and X^2 comparing mothers with and without missing breastfeeding initiation data. [d] Standardised factor score where higher scores indicate greater socioeconomic disadvantage. [e] IMD = 2010 Index of Multiple Deprivation score where higher scores indicate greater deprivation.

Table 3.2: Unadjusted associations between socioeconomic position and environmental quality indicators for a) White British mothers, b) Pakistani-origin mothers and c) all mothers

a) White British mothers (n=3,951)

	Socioeconomic disadvantage				Neighbourhood deprivation			
Physical environmental quality	**n**	**Coef.**	**95% CI**	**P-value**	**n**	**Coef.**	**95% CI**	**P-value**
Water disinfectant by-products								
Total trihalomethanes	3,863	0.137	0.083-0.191	**<0.001**	3,861	0.008	0.005-0.011	**<0.001**
Brominated trihalomethanes	3,863	0.026	0.019-0.032	**<0.001**	3,861	0.001	0.001-0.002	**<0.001**
Bromodichloromethane	3,863	0.021	0.016-0.026	**<0.001**	3,861	0.001	0.001-0.001	**<0.001**
Dibromochloromethane	3,863	0.002	0.001-0.003	**<0.001**	3,861	0.000	0.000-0.000	**0.021**
Chloroform	3,863	0.112	0.064-0.160	**<0.001**	3,861	0.007	0.004-0.010	**<0.001**
Air pollution								
Nitrogen oxides	3,809	0.012	0.002-0.023	**0.025**	3,807	0.001	0.001-0.002	**<0.001**
Nitrogen dioxide	3,809	0.025	0.016-0.035	**<0.001**	3,807	0.003	0.002-0.004	**<0.001**
Passive cigarette smoke	3,936	0.618	0.556-0.679	**<0.001**	3,934	0.029	0.026-0.033	**<0.001**
Household condition								
No central heating	834	0.255	-0.019-0.528	***0.068***	833	0.001	-0.016-0.017	0.919
Damp and/or mould	1,013	0.235	0.101-0.370	**0.001**	1,012	0.011	0.003-0.019	**0.007**

b) Pakistani-origin mothers (n=4,411)

	Socioeconomic disadvantage				Neighbourhood deprivation			
Physical environmental quality	**n**	**Coef.**	**95% CI**	**P-value**	**n**	**Coef.**	**95% CI**	**P-value**
Water disinfectant by-products								
Total trihalomethanes	4,341	-0.027	-0.061-0.008	0.134	4,341	-0.001	-0.004-0.001	0.228
Brominated trihalomethanes	4,341	-0.001	-0.005-0.004	0.807	4,341	-0.000	-0.000-0.000	0.378
Bromodichloromethane	4,341	-0.001	0.005-0.003	0.691	4,341	-0.000	-0.000-0.000	0.463
Dibromochloromethane	4,341	0.000	-0.001-0.000	0.315	4,341	0.000	0.000-0.000	**0.008**
Chloroform	4,341	-0.026	-0.056-0.004	***0.092***	4,341	-0.001	-0.003-0.001	0.212
Air pollution								
Nitrogen oxides	4,312	0.041	0.029-0.053	**<0.001**	4,312	0.008	0.007-0.009	**<0.001**
Nitrogen dioxide	4,312	0.039	0.028-0.050	**<0.001**	4,312	0.009	0.008-0.010	**<0.001**
Passive cigarette smoke	4,377	0.122	0.055-0.189	**<0.001**	4,376	0.000	-0.004-0.005	0.866
Household condition								
No central heating	1,046	-0.032	-0.288-0.224	0.808	1,046	0.038	0.019-0.058	**<0.001**
Damp and/or mould	1,519	0.114	-0.009-0.237	***0.069***	1,519	0.017	0.009-0.026	**<0.001**

c) All mothers (n=12,087)

Physical environmental quality	n	Coef.	95% CI	P-value	n	Coef.	95% CI	P-value
	Socioeconomic disadvantage				**Neighbourhood deprivation**			
Water disinfectant by-products								
Total trihalomethanes	9,714	0.038	0.008-0.067	**0.012**	9,712	-0.002	-0.004--0.000	**0.030**
Brominated trihalomethanes	9,714	0.010	0.006-0.013	**<0.001**	9,712	-0.000	-0.000-0.000	0.156
Bromodichloromethane	9,714	0.008	0.005-0.011	**<0.001**	9,712	0.000	0.000-0.000	0.429
Dibromochloromethane	9,714	0.001	0.000-0.001	***0.053***	9,712	0.000	0.000-0.000	**<0.001**
Chloroform	9,714	0.028	0.002-0.054	**0.035**	9,712	-0.002	-0.003-0.000	**0.024**
Air pollution								
Nitrogen oxides	9,629	0.035	0.028-0.043	**<0.001**	9,626	0.006	0.005-0.006	**<0.001**
Nitrogen dioxide	9,629	0.038	0.031-0.045	**<0.001**	9,626	0.007	0.006-0.007	**<0.001**
Passive cigarette smoke	9,839	0.35	0.312-0.392	**<0.001**	9,836	0.010	0.008-0.013	**<0.001**
Household condition								
No central heating	2,198	0.13	-0.039-0.296	0.134	2,197	0.014	0.004-0.025	**0.007**
Damp and/or mould	2,932	0.17	0.086-0.253	**<0.001**	2,931	0.011	0.006-0.016	**<0.001**

Each row refers to a separate model, as we ran individual models for each physical environmental quality indicator. Linear regression used for all indicators except for passive cigarette smoke, no central heating and damp and/or mould associations which were tested with logistic regression. Excludes mothers missing breastfeeding initiation data. Neighbourhood deprivation measured by the 2010 index of multiple deprivation score and socioeconomic disadvantage measured by our standardised socioeconomic position score (higher scores correspond to greater disadvantage for both measures). Positive coefficients represent predicted direction of association, whereby greater disadvantage is associated with greater environmental exposure.

Table 3.3: Associations between physical environmental quality and breastfeeding initiation for a) White British mothers, b) Pakistani-origin mothers and c) mothers of all ethnicities

a) White British mothers

	M1: Controlling for maternal and infant characteristics				M2: Controlling for maternal and infant characteristics and socioeconomic position		
	n	**OR**	**95% CI**	**P-value**	**OR**	**95% CI**	**P-value**
Socioeconomic disadvantage [a]	3,589	-	-	-	0.772	0.712-0.837	**<0.001**
Physical environmental quality							
Water disinfectant by-products							
Total trihalomethanes	3,517						
1.05-1.82μg/day vs <1.05μg/day		1.005	0.827-1.221	0.962	1.005	0.826-1.222	0.962
1.82-23.96μg/day vs <1.05μg/day		1.139	0.946-1.370	0.169	1.150	0.955-1.385	0.141
Brominated trihalomethanes	3,517						
0.14-0.26μg/day vs <0.14μg/day		0.904	0.742-1.101	0.316	0.901	0.739-1.099	0.304
0.26-3.34μg/day vs <0.14μg/day		1.031	0.853-1.246	0.753	1.045	0.864-1.264	0.652
Bromodichloromethane	3,517						
0.12-0.21μg/day vs <0.12μg/day		0.897	0.737-1.092	0.279	0.896	0.736-1.092	0.276
0.21-2.61μg/day vs <0.12μg/day		1.041	0.862-1.259	0.675	1.057	0.874-1.279	0.567
Dibromochloromethane	3,517						
0.02-0.03μg/day vs <0.02μg/day		0.879	0.722-1.069	0.196	0.881	0.724-1.073	0.207
0.03-0.61μg/day vs <0.02μg/day		1.140	0.949-1.370	0.162	1.150	0.956-1.383	0.139
Chloroform	3,517						
0.91-1.56μg/day vs <0.91μg/day		1.020	0.840-1.239	0.840	1.023	0.841-1.244	0.819
1.56-20.94μg/day vs <0.91μg/day		1.150	0.957-1.382	0.137	1.167	0.969-1.404	0.103
Air pollution							
Nitrogen oxides (20μg/m³)	3,477	0.884	0.729-1.073	0.212	0.905	0.745-1.100	0.317
Nitrogen dioxide (10μg/m³)	3,477	0.772	0.631-0.945	**0.012**	0.806	0.657-0.988	**0.038**
Passive cigarette smoke	3,578	0.888	0.757-1.041	0.142	0.961	0.817-1.130	0.629
Household condition							
No central heating	778	0.692	0.337-1.419	0.315	0.738	0.359-1.518	0.410
Damp and/or mould	939	1.570	1.058-2.329	**0.025**	1.655	1.109-2.470	**0.014**

b) Pakistani-origin mothers

		M1: Controlling for maternal and infant characteristics			M2: Controlling for maternal and infant characteristics and socioeconomic position		
	n	**OR**	**95% CI**	**P-value**	**OR**	**95% CI**	**P-value**
Socioeconomic disadvantage [a]	3,979	-	-	-	0.797	0.743-0.854	**<0.001**
Physical environmental quality							
Water disinfectant by-products							
Total trihalomethanes	3,939						
1.05-1.82µg/day vs <1.05µg/day		0.792	0.682-0.919	**0.002**	0.774	0.666-0.900	**0.001**
1.82-23.96µg/day vs <1.05µg/day		0.774	0.653-0.919	**0.003**	0.765	0.644-0.908	**0.002**
Brominated trihalomethanes	3,939						
0.14-0.26µg/day vs <0.14µg/day		0.756	0.651-0.878	**<0.001**	0.744	0.640-0.865	**<0.001**
0.26-3.34µg/day vs <0.14µg/day		0.756	0.637-0.898	**0.001**	0.753	0.633-0.895	**0.001**
Bromodichloromethane	3,939						
0.12-0.21µg/day vs <0.12µg/day		0.770	0.663-0.895	**0.001**	0.756	0.651-0.879	**<0.001**
0.21-2.61µg/day vs <0.12µg/day		0.775	0.653-0.920	**0.004**	0.768	0.646-0.912	**0.003**
Dibromochloromethane	3,939						
0.02-0.03µg/day vs <0.02µg/day		0.721	0.622-0.836	**<0.001**	0.717	0.617-0.832	**<0.001**
0.03-0.61µg/day vs <0.02µg/day		0.696	0.586-0.828	**<0.001**	0.695	0.584-0.827	**<0.001**
Chloroform	3,939						
0.91-1.56µg/day vs <0.91µg/day		0.801	0.690-0.930	**0.004**	0.782	0.673-0.909	**0.001**
1.56-20.94µg/day vs <0.91µg/day		0.769	0.648-0.912	**0.003**	0.759	0.639-0.901	**0.002**
Air pollution							
Nitrogen oxides (20µg/m³)	3,907	0.693	0.593-0.810	**<0.001**	0.730	0.623-0.854	**<0.001**
Nitrogen dioxide (10µg/m³)	3,907	0.748	0.633-0.885	**0.001**	0.789	0.666-0.935	**0.006**
Passive cigarette smoke	3,956	0.950	0.817-1.104	0.504	0.992	0.852-1.155	0.919
Household condition							
No central heating	970	0.584	0.287-1.186	0.137	0.624	0.303-1.285	0.200
Damp and/or mould	1,411	1.344	0.919-1.968	0.128	1.415	0.964-2.076	***0.076***

c) All mothers

		M1: Controlling for maternal and infant characteristics			M2: Controlling for maternal and infant characteristics and socioeconomic position		
	n	**OR**	**95% CI**	**P-value**	**OR**	**95% CI**	**P-value**
Socioeconomic disadvantage [a]	8,955	-	-	-	0.776	0.739-0.814	**<0.001**
Physical environmental quality							
Water disinfectant by-products							
Total trihalomethanes	8,825						
1.05-1.82µg/day vs <1.05µg/day		0.855	0.767-0.954	**0.005**	0.837	0.750-0.933	**0.001**
1.82-23.96µg/day vs <1.05µg/day		0.905	0.807-1.013	***0.083***	0.895	0.798-1.003	***0.056***
Brominated trihalomethanes	8,825						
0.14-0.26µg/day vs <0.14µg/day		0.864	0.775-0.963	**0.008**	0.845	0.758-0.943	**0.003**
0.26-3.34µg/day vs <0.14µg/day		0.942	0.841-1.054	0.297	0.929	0.829-1.040	0.201
Bromodichloromethane	8,825						
0.12-0.21µg/day vs <0.12µg/day		0.860	0.772-0.959	**0.007**	0.841	0.753-0.938	**0.002**
0.21-2.61µg/day vs <0.12µg/day		0.910	0.813-1.020	0.105	0.900	0.803-1.009	***0.070***
Dibromochloromethane	8,825						
0.02-0.03µg/day vs <0.02µg/day		0.810	0.727-0.902	**<0.001**	0.800	0.717-0.891	**<0.001**
0.03-0.61µg/day vs <0.02µg/day		0.926	0.827-1.036	0.180	0.916	0.818-1.026	0.130
Chloroform	8,825						
0.91-1.56µg/day vs <0.91µg/day		0.872	0.782-0.972	**0.013**	0.853	0.765-0.951	**0.004**
1.56-20.94µg/day vs <0.91µg/day		0.944	0.844-1.057	0.319	0.933	0.833-1.045	0.229
Air pollution							
Nitrogen oxides (20µg/m^3)	8,751	0.774	0.694-0.865	**<0.001**	0.813	0.727-0.909	**<0.001**
Nitrogen dioxide (10µg/m^3)	8,751	0.766	0.682-0.861	**<0.001**	0.810	0.720-0.911	**<0.001**
Passive cigarette smoke	8,916	0.910	0.823-1.007	***0.067***	0.966	0.872-1.069	0.501
Household condition							
No central heating	2,046	0.736	0.454-1.193	0.214	0.787	0.484-1.281	0.336
Damp and/or mould	2,725	1.448	1.116-1.878	**0.005**	1.524	1.171-1.983	**0.002**

Models adjusted for cohabitation status, immigration status, BMI, age, parity, smoking during pregnancy, the sex of the infant and whether it was a multiple birth (M1) and additionally socioeconomic position (M2). OR=odds ratio. CI=confidence interval. Each row in the table refers to a separate model, as we ran individual models for each physical environmental quality indicator. [a] Odds for one standard deviation increase in socioeconomic disadvantage.

Table 3.4: Associations between physical environmental quality and breastfeeding duration for a) White British mothers, b) Pakistani-origin mothers and c) mothers of all ethnicities

a) White British mothers

		M1: Controlling for maternal and infant characteristics			M2: Controlling for maternal and infant characteristics and socioeconomic position		
	n	**HR**	**95% CI**	**P-value**	**HR**	**95% CI**	**P-value**
Socioeconomic disadvantage [a]	843	-	-	-	1.105	1.013-1.204	**0.024**
Physical environmental quality							
Water disinfectant by-products							
Total trihalomethanes	829						
1.05-1.82μg/day vs <1.05μg/day		0.995	0.814-1.216	0.959	0.999	0.818-1.222	0.996
1.82-23.96μg/day vs <1.05μg/day		0.934	0.768-1.136	0.497	0.923	0.759-1.123	0.425
Brominated trihalomethanes	829						
0.14-0.26μg/day vs <0.14μg/day		0.976	0.799-1.192	0.811	0.985	0.806-1.203	0.882
0.26-3.34μg/day vs <0.14μg/day		0.910	0.747-1.109	0.352	0.903	0.741-1.101	0.313
Bromodichloromethane	829						
0.12-0.21μg/day vs <0.12μg/day		0.964	0.790-1.177	0.720	0.975	0.799-1.189	0.800
0.21-2.61μg/day vs <0.12μg/day		0.905	0.743-1.102	0.321	0.895	0.734-1.090	0.271
Dibromochloromethane	829						
0.02-0.03μg/day vs <0.02μg/day		1.061	0.868-1.298	0.564	1.070	0.875-1.309	0.509
0.03-0.61μg/day vs <0.02μg/day		0.920	0.758-1.117	0.402	0.913	0.751-1.108	0.356
Chloroform	829						
0.91-1.56μg/day vs <0.91μg/day		0.959	0.785-1.173	0.686	0.960	0.786-1.173	0.691
1.56-20.94μg/day vs <0.91μg/day		0.919	0.756-1.116	0.392	0.906	0.745-1.101	0.321
Air pollution							
Nitrogen oxides (20μg/m³)	814	0.786	0.633-0.976	**0.029**	0.769	0.619-0.955	**0.018**
Nitrogen dioxide (10μg/m³)	814	0.671	0.540-0.834	**<0.001**	0.646	0.519-0.804	**<0.001**
Passive cigarette smoke	841	1.082	0.908-1.290	0.378	1.054	0.883-1.258	0.559
Household condition							
No central heating	552	0.903	0.546-1.493	0.691	0.898	0.543-1.484	0.674
Damp and/or mould	662	0.924	0.747-1.144	0.469	0.930	0.752-1.151	0.505

b) Pakistani-origin mothers

	M1: Controlling for maternal and infant characteristics				M2: Controlling for maternal and infant characteristics and socioeconomic position		
	n	**HR**	**95% CI**	**P-value**	**HR**	**95% CI**	**P-value**
Socioeconomic disadvantage [a]	1,346	-	-	-	1.125	1.058-1.196	**<0.001**
Physical environmental quality							
Water disinfectant by-products							
Total trihalomethanes	1,338						
1.05-1.82µg/day vs <1.05µg/day		1.046	0.916-1.193	0.507	1.054	0.923-1.202	0.437
1.82-23.96µg/day vs <1.05µg/day		1.123	0.962-1.310	0.141	1.130	0.968-1.319	0.122
Brominated trihalomethanes	1,338						
0.14-0.26µg/day vs <0.14µg/day		1.093	0.956-1.251	0.193	1.105	0.966-1.264	0.147
0.26-3.34µg/day vs <0.14µg/day		1.149	0.984-1.341	***0.078***	1.149	0.984-1.342	***0.079***
Bromodichloromethane	1,338						
0.12-0.21µg/day vs <0.12µg/day		1.100	0.961-1.259	0.165	1.110	0.970-1.270	0.130
0.21-2.61µg/day vs <0.12µg/day		1.132	0.971-1.321	0.114	1.136	0.974-1.325	0.105
Dibromochloromethane	1,338						
0.02-0.03µg/day vs <0.02µg/day		1.203	1.053-1.374	**0.006**	1.210	1.059-1.382	**0.005**
0.03-0.61µg/day vs <0.02µg/day		1.165	0.996-1.363	***0.056***	1.162	0.994-1.360	***0.060***
Chloroform	1,338						
0.91-1.56µg/day vs <0.91µg/day		1.025	0.899-1.170	0.708	1.033	0.905-1.178	0.631
1.56-20.94µg/day vs <0.91µg/day		1.114	0.955-1.300	0.169	1.121	0.961-1.308	0.147
Air pollution							
Nitrogen oxides (20µg/m³)	1,323	1.051	0.910-1.213	0.501	1.019	0.881-1.179	0.799
Nitrogen dioxide (10µg/m³)	1,323	0.953	0.825-1.102	0.517	0.928	0.802-1.074	0.316
Passive cigarette smoke	1,337	1.111	0.972-1.270	0.124	1.085	0.948-1.241	0.235
Household condition							
No central heating	825	0.989	0.715-1.367	0.946	0.987	0.714-1.365	0.938
Damp and/or mould	1,070	1.028	0.882-1.197	0.725	0.990	0.849-1.154	0.896

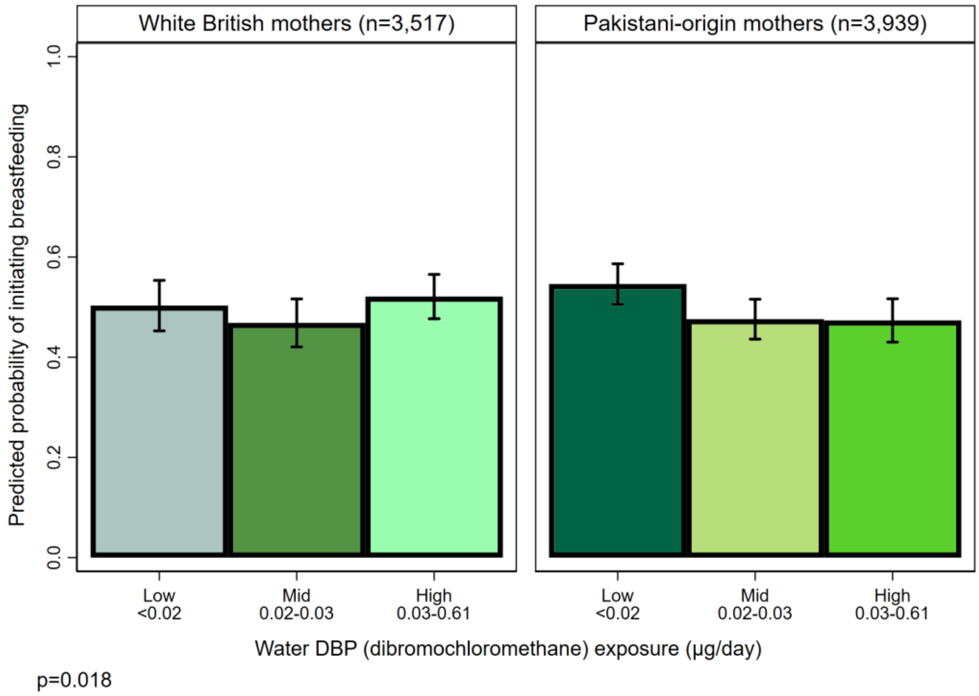
c) All mothers

	M1: Controlling for maternal and infant characteristics				M2: Controlling for maternal and infant characteristics and socioeconomic position		
	n	**HR**	**95% CI**	**P-value**	**HR**	**95% CI**	**P-value**
Socioeconomic disadvantage [a]	2,635	-	-	-	1.108	1.060-1.159	**<0.001**
Physical environmental quality							
Water disinfectant by-products							
Total trihalomethanes	2,608						
1.05-1.82µg/day vs <1.05µg/day		0.986	0.892-1.090	0.783	0.996	0.901-1.102	0.942
1.82-23.96µg/day vs <1.05µg/day		0.991	0.890-1.104	0.873	0.991	0.890-1.104	0.871
Brominated trihalomethanes	2,608						
0.14-0.26µg/day vs <0.14µg/day		0.984	0.889-1.088	0.749	0.996	0.901-1.102	0.945
0.26-3.34µg/day vs <0.14µg/day		1.003	0.900-1.117	0.962	1.003	0.901-1.118	0.951
Bromodichloromethane	2,608						
0.12-0.21µg/day vs <0.12µg/day		0.980	0.886-1.084	0.701	0.992	0.897-1.098	0.882
0.21-2.61µg/day vs <0.12µg/day		1.000	0.898-1.113	0.994	0.999	0.897-1.113	0.987
Dibromochloromethane	2,608						
0.02-0.03µg/day vs <0.02µg/day		1.059	0.958-1.172	0.262	1.068	0.966-1.182	0.200
0.03-0.61µg/day vs <0.02µg/day		1.018	0.915-1.133	0.744	1.016	0.913-1.131	0.773
Chloroform	2,608						
0.91-1.56µg/day vs <0.91µg/day		0.969	0.876-1.071	0.537	0.978	0.884-1.081	0.661
1.56-20.94µg/day vs <0.91µg/day		0.981	0.881-1.092	0.724	0.981	0.881-1.092	0.724
Air pollution							
Nitrogen oxides (20µg/m³)	2,580	0.937	0.841-1.043	0.233	0.911	0.817-1.015	***0.092***
Nitrogen dioxide (10µg/m³)	2,580	0.833	0.749-0.927	**0.001**	0.805	0.723-0.897	**<0.001**
Passive cigarette smoke	2,624	1.145	1.040-1.260	**0.006**	1.120	1.017-1.234	**0.021**
Household condition							
No central heating	1,651	0.939	0.742-1.189	0.601	0.930	0.734-1.177	0.546
Damp and/or mould	2,065	0.953	0.851-1.066	0.401	0.935	0.836-1.047	0.245

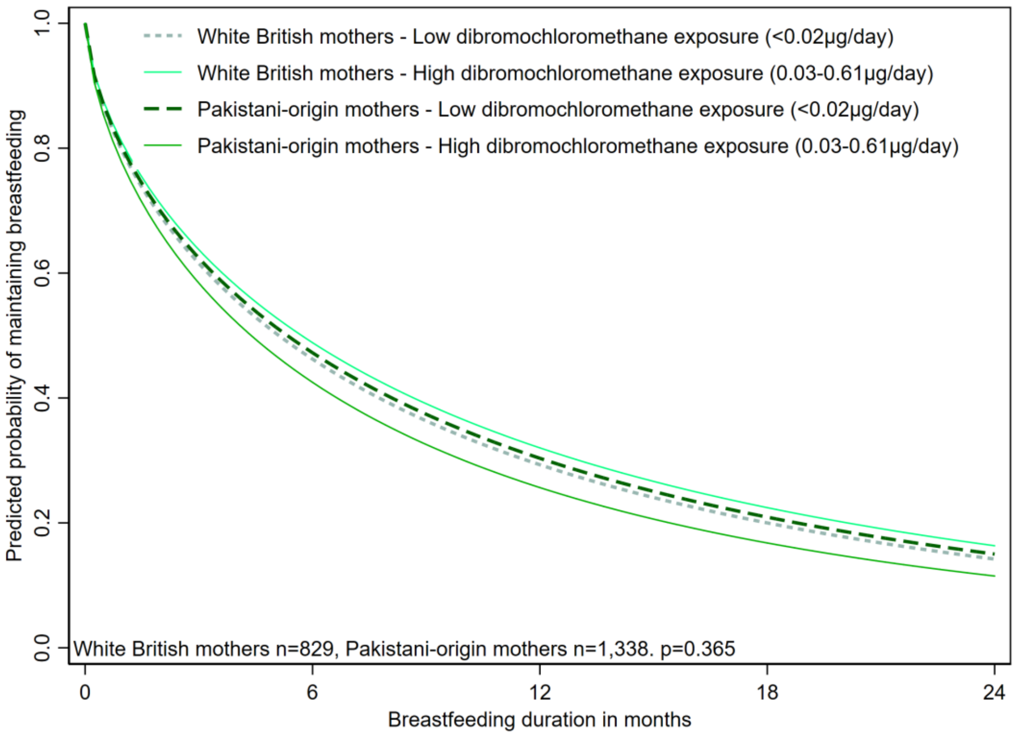
Models adjusted for cohabitation status, immigration status, BMI, age, parity, smoking during pregnancy, the sex of the infant and whether it was a multiple birth (M1) and additionally socioeconomic position (M2). HR=hazard ratio of stopping breastfeeding. CI=confidence interval. Each row in the table refers to a separate model, as we ran individual models for each physical environmental quality indicator. a Odds for one standard deviation increase in socioeconomic disadvantage.

*Figure 3.1: **Predicted probabilities of breastfeeding initiation and breastfeeding duration by physical environmental quality indicators and ethnicity.** All models represented in the figures are restricted to just White British and Pakistani-origin mothers and include an ethnicity x exposure interaction, and are adjusted for maternal and infant characteristics and socioeconomic position.*

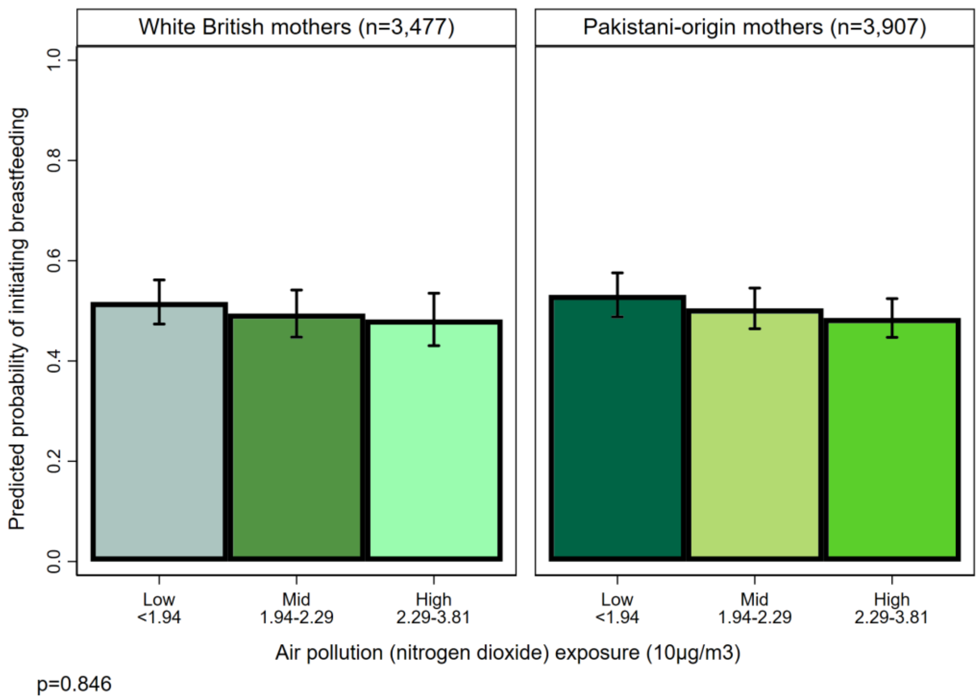
a) *Predicted probability of initiating breastfeeding by dibromochloromethane (water disinfectant by-product) exposure and ethnicity*



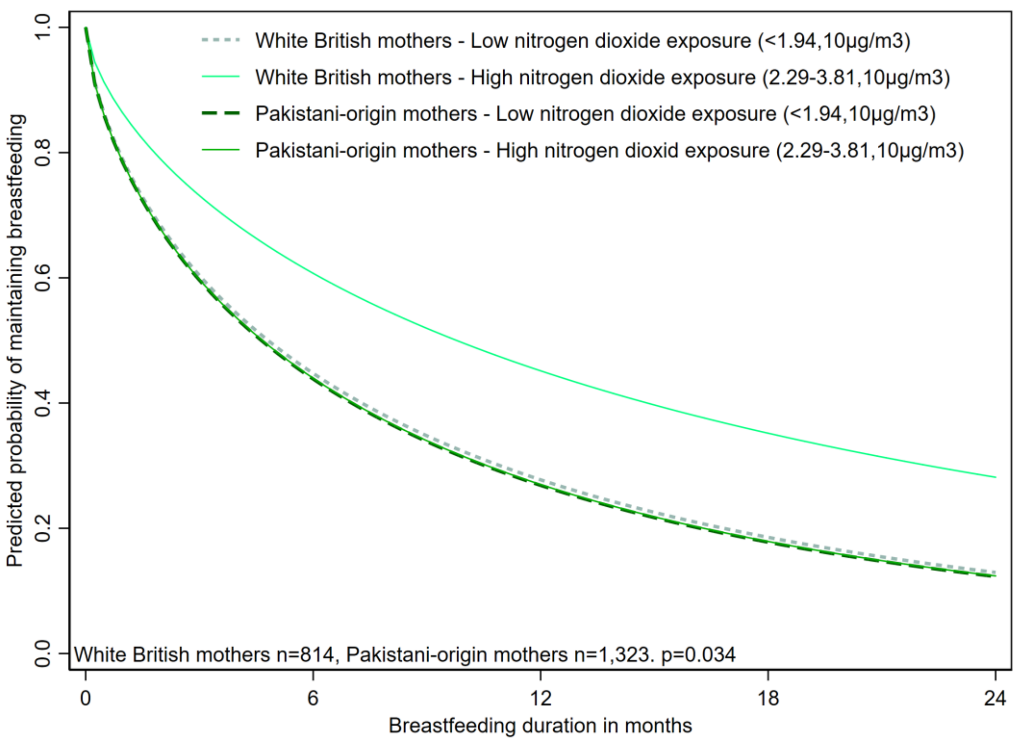
b) *Predicted probability of maintaining breastfeeding by dibromochloromethane (water disinfectant by-product) exposure and ethnicity*



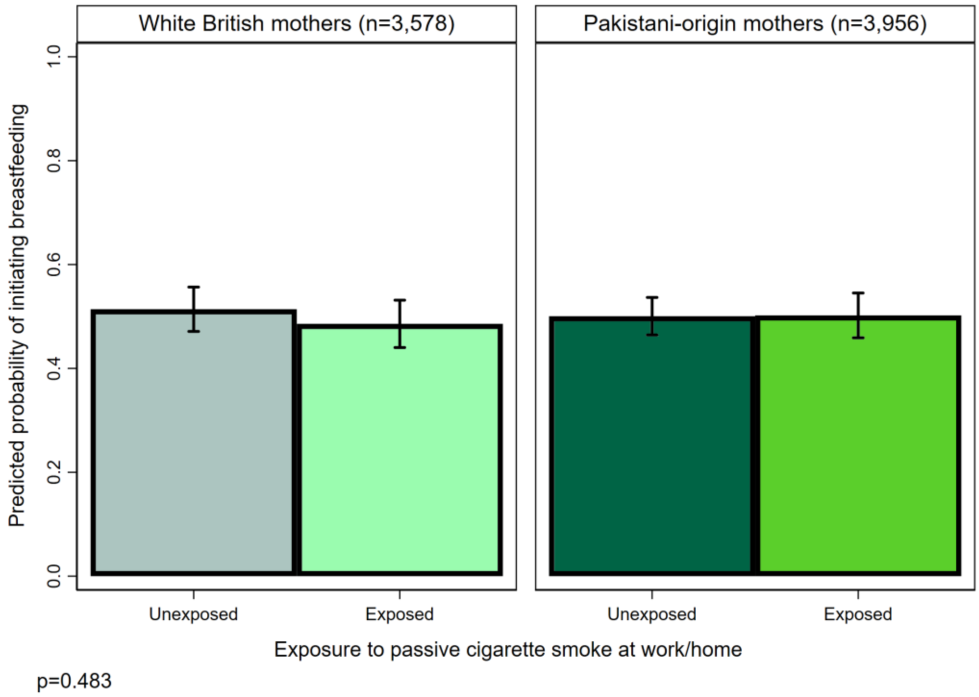
c) Predicted probability of initiating breastfeeding by nitrogen dioxide (air pollution) exposure and ethnicity



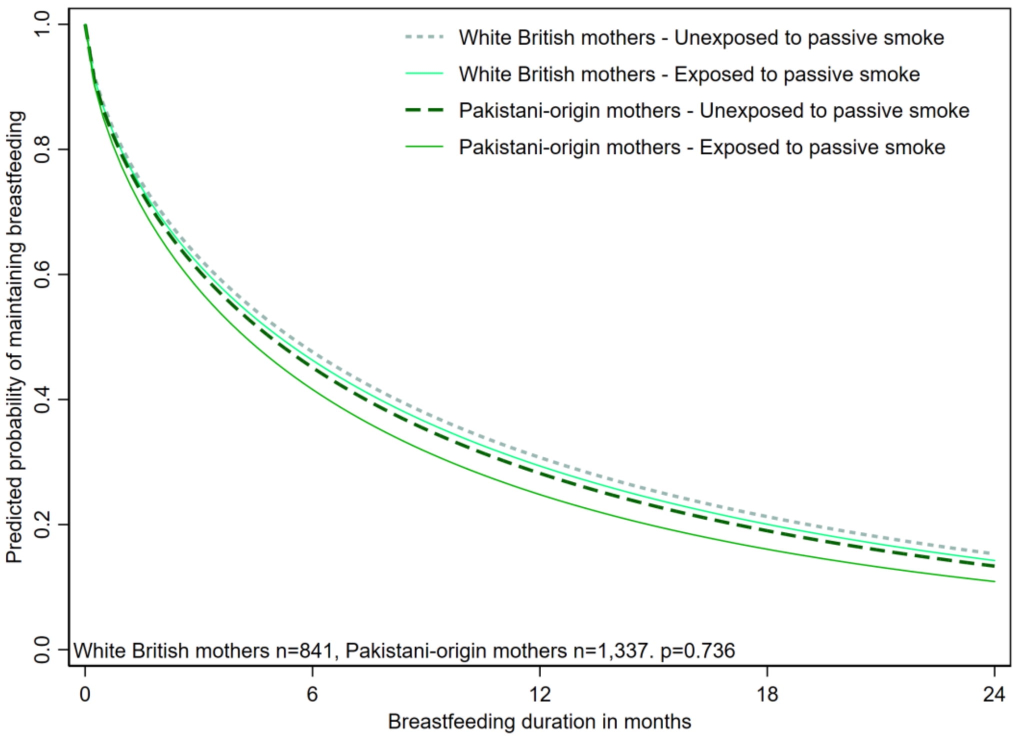
d) Predicted probability of maintaining breastfeeding by nitrogen dioxide (air pollution) exposure and ethnicity



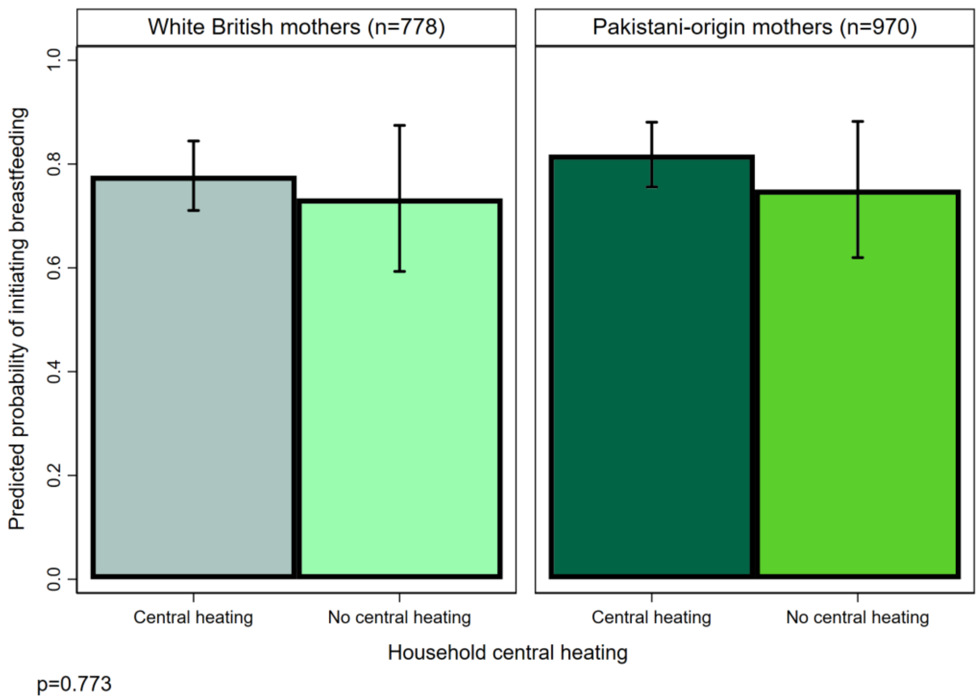
e) Predicted probability of initiating breastfeeding by passive smoke exposure and ethnicity



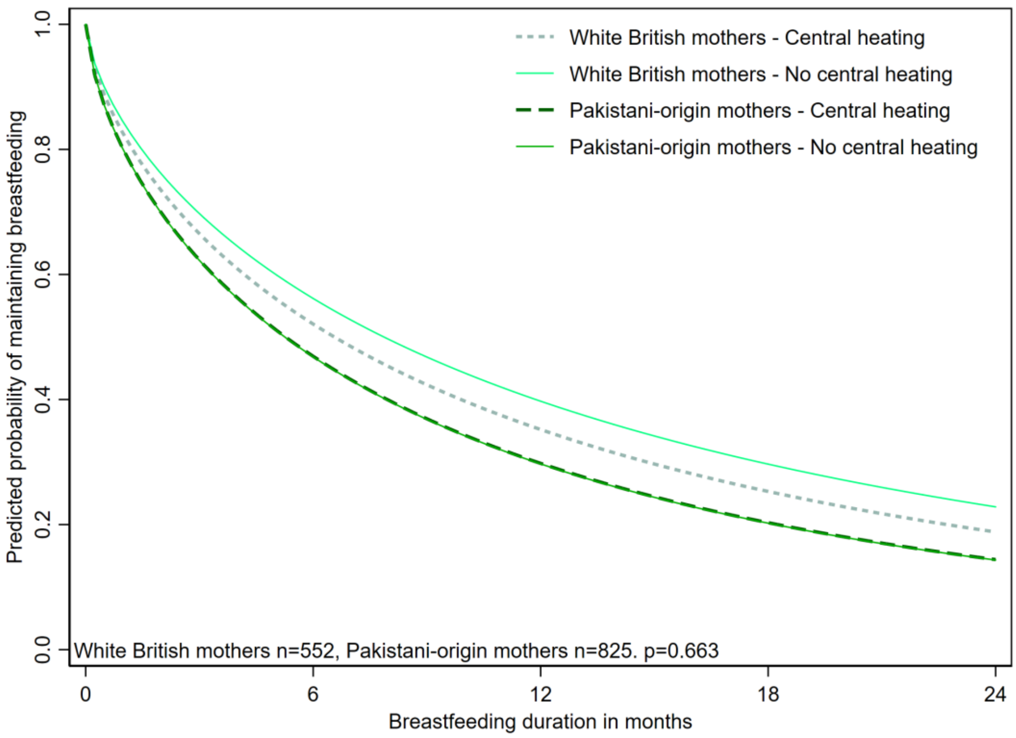
f) Predicted probability of maintaining breastfeeding by passive smoke exposure and ethnicity



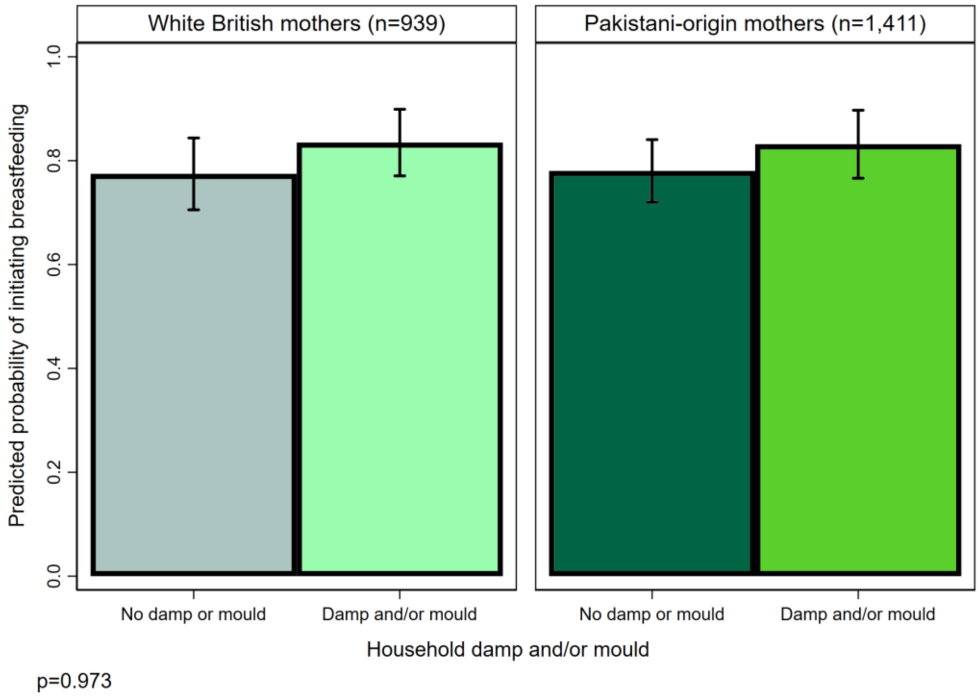
g) Predicted probability of initiating breastfeeding by household central heating and ethnicity



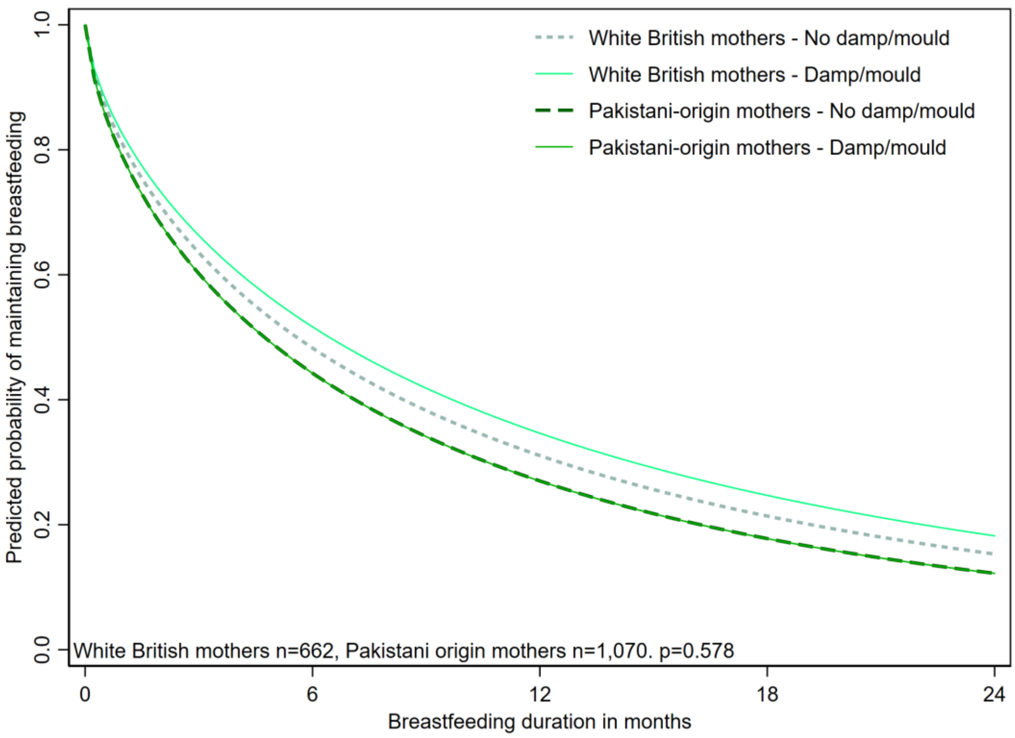
h) Predicted probability of maintaining breastfeeding by household central heating and ethnicity



i) Predicted probability of initiating breastfeeding by household damp and/or mould exposure and ethnicity



j) Predicted probability of maintaining breastfeeding by household damp and/or mould exposure and ethnicity



3.6 DISCUSSION

We predicted that mothers with poorer environmental quality i.e. greater exposure to environmental pollutants and worse household condition would be less likely to initiate breastfeeding and have higher hazards of stopping breastfeeding. We found mixed associations between physical environmental quality indicators and breastfeeding outcomes, with the direction and strength of relationship varying by indicator and ethnicity; broadly, though, the relationships between environmental quality and breastfeeding initiation showed stronger support for our hypothesis than those between environmental quality and breastfeeding duration (the hazard of stopping breastfeeding). Relationships were, perhaps surprisingly, little affected by the inclusion of socioeconomic position in models. This suggests that physical environmental quality and socioeconomic position may be separate axes of influence on breastfeeding, with some aspects of physical environmental quality impacting breastfeeding above and beyond the well-established social and economic barriers.

3.6.1 Ethnic differences in breastfeeding outcomes

Pakistani-origin mothers had higher breastfeeding initiation rates and longer average breastfeeding durations than White-British mothers in our sample. It could be that varying cultural influences contribute to this difference, with for example protective Islamic beliefs (Williamson & Sacranie, 2012; Zaidi, 2014), South Asian cultural teachings (Choudhry & Wallace, 2012) and more extensive support networks (GOV.UK, 2018) amongst Pakistani-origin mothers playing a key role. In addition, as Table 3.1 shows, only a small proportion of Pakistani-origin mothers in our sample were born in the UK; our measures of physical environmental quality and socioeconomic disadvantage do not capture earlier life exposure and it may be that Pakistani-origin mothers' breastfeeding outcomes would be better predicted by earlier exposure in Pakistan than by contemporary exposure in the UK.

Acculturation also influences breastfeeding practices; it can be thought of as the extent to which people from one culture adapt their behaviour to reflect the norms of another cultural group. This may explain the relatively similar breastfeeding durations between the two ethnic groups in our study. The detrimental influence of UK societal norms on immigrant breastfeeding chances have been reported quantitatively for immigrants generally (Hawkins et al., 2008) and qualitatively for those immigrating from South Asian countries specifically (Choudhry & Wallace, 2012). For example, previous analyses using the Millennium Cohort Study have shown that whilst babies of South Asian descent had similar odds of being breastfed to White babies, immigrant mothers were less likely to initiate breastfeeding the longer they lived in the UK (L.J. Brown & Sear, 2017 [Supplementary material]; Hawkins et al., 2008).

3.6.2 Reduced breastfeeding in harsh environments

The water DBP results for both breastfeeding outcomes for Pakistani-origin mothers and the air pollution breastfeeding initiation results for both ethnic groups support our hypothesis that mothers are less likely to breastfeed in poorer-quality environments. Although we did not find associations between passive smoke exposure and breastfeeding in our study (in part likely due to controlling for maternal smoking), links between smoking and breastfeeding in the literature may provide clues as to how air pollution could directly impact breastfeeding initiation. For example, air pollution may have a similar negative impact on milk ejection, output, taste and composition as well as on infant irritability and appetite (L. H. Amir, 2001). Our water DBP findings are in line with previous BiB research that found trihalomethane exposure was negatively associated with birthweight but only in Pakistani-origin infants (R. B. Smith et al., 2016). Whilst we found no evidence for mediation by birthweight, together Smith's study and ours suggest that Pakistani-origin mothers are particularly vulnerable to DBPs even though their exposure is lower. DBPs concentrate in fatty tissues, accumulating over the life course and mobilising during gestation and lactation (Colborn, Vom Saal, & Soto, 1993; Freire et al., 2011). The rate of elimination depends on the amount of fat a person has (World Health Organization, 2005) and, as South Asian populations have more fat mass than Europeans (Deurenberg, Deurenberg-Yap, & Guiricci, 2002; Stanfield, Wells, Fewtrell, Frost, & Leon, 2012), the Pakistani-origin mothers in our sample may have retained DBPs in their bodies for longer, resulting in greater physiological impact. The compounds may impact breast development and lactation (Bielmeier, Best, & Narotsky, 2004; Rosen-Carole, Auinger, Howard, Brownell, & Lanphear, 2017) and may transfer from mother to infant (Batterman, Zhang, Wang, & Franzblau, 2002), potentially altering the taste and acceptability of breastmilk (Office of Environmental Health Hazard Assessment California Environmental Protection Agency, 2010). Alternatively, rather than being driven by physiological variation, the observed ethnic differences could be explained by social factors not controlled for e.g. diet and stress (R. B. Smith et al., 2016), or even fertility (although further data exploration shows this to be unlikely (results available on request)). Differences in childhood experiences (Belsky, 2012; Hartman, Li, Nettle, & Belsky, 2017) may also account for the ethnic differences in our results to some extent.

3.6.3 Breastfeeding as protection from environmental harm?

Our finding that White British mothers had reduced hazards of stopping breastfeeding (i.e. longer durations) when exposed to more air pollution is contrary to our prediction, but could perhaps reflect mothers using breastfeeding to protect their infants from environmental harm. Breastfeeding provides greater antioxidative protection than formula feeding (Shoji & Koletzko, 2007) and may counteract some of the detrimental health impacts of prenatal exposure to environmental contaminants (Guxens et al., 2012), such as respiratory problems (Naz, Page, & Agho, 2016) and impaired motor and cognitive development (Lertxundi et al., 2015). Similarly, the positive damp/mould-initiation relationship could also be explained by the protective effect of breastfeeding against the associated risks of asthma and allergies (Flohr et al., 2018; Klopp et al., 2017; Lodge et al., 2015; Silvers et al., 2012; Sonnenschein-van Der Voort et al., 2012; Tischer et al., 2011). It is however not clear why only White British mothers showed these associations.

3.6.4 Mediation by birth outcomes

Whilst we did not find evidence that passive smoke exposure impacts breastfeeding directly, our mediation results suggest that it may restrict foetal growth, manifesting as lower birthweight with the knock-on effect of mothers being less likely to initiate breastfeeding for these smaller infants. Compounds in cigarette smoke may cause oxidative stress to the foetal-placental unit (Erickson & Arbour, 2014) resulting in smaller neonates.

Our finding that some of the association between greater air pollution exposure and *reduced* hazards of stopping breastfeeding was mediated through longer gestational lengths, whilst counter to our prediction of greater exposure, smaller neonates and lower breastfeeding chances, is echoed to some extent by findings from other studies. For example, air pollution studies in Italy (Sabatino et al., 2015) and Australia (Jalaludin et al., 2007) found that greater exposure to air pollutants was associated with a *reduced* risk of having a preterm birth. Looking specifically at exposure to nitrogen oxides in these studies results are however more mixed: greater nitrogen dioxide exposure during the first trimester was associated with *reduced* preterm birth risk in the Australian study but greater exposure in the second trimester was associated with *increased* preterm birth risk in the Italian study. Mixed evidence for associations between nitrogen oxides and birth outcomes notwithstanding (Shah & Balkhair, 2011), it is possible that a longer gestation could serve as mechanism by which to compensate for maternal hypoxemic-hypoxic damage (Sabatino et al., 2015).

Taken together these mediation results suggest that mothers with low birthweight and shorter gestation lengths have reduced breastfeeding chances, a finding corroborated by our previous analyses of the Millennium Cohort Study (L.J. Brown & Sear, 2017) which showed that lower birthweight infants had lower initiation rates and average breastfeeding durations (e.g. 67 % and 2.07 months vs 69% and 2.69 months for normal weight, and 74% and 3.11 months for heavy weight). Low birthweight and preterm birth (i.e. when gestational lengths are shorter than 37 weeks) may negatively impact breastfeeding in several ways. Mothers of low birthweight infants often experience difficulties that are not common to women giving birth to healthy full-term infants. For example, some of the underlying causes of preterm birth (hypertension, diabetes and maternal obesity) negatively influence breastmilk production (De Freitas, Lima, Carlos, Priore, & Do Carmo Castro Franceschini, 2016). Recovering from a complicated pregnancy or delivery, feeling tired of depressed after prolonged hospitalisation, or feeling anxious due to the baby’s real or apprehended condition and mourning a twin are also additional risk factors (Lefebvre, 1990; Tommy’s, 2019). The baby may be more likely to be separated from the mother to be taken to the intensive care unit or to have various tests and treatments (Adamkin, 2006; De Freitas et al., 2016; Dodrill, 2011; Lefebvre, 1990). In terms of infant factors, low birthweight or preterm babies are more likely to be part of a twin or triplet set, to be sleepier and have less stamina, and exhibit signs of weakness including extreme immaturity and thermal instability and illness (including critical conditions on respirators) (Adamkin, 2006; Lefebvre, 1990). These small babies are more likely to suck poorly (with immature or dysfunctional sucking skills and poor suck-swallow-breathe coordination) or to refuse the breast; they are less likely to be discharged exclusively breastfeeding, with mothers more likely to report feeding problems after discharge too (Dodrill, 2011; Lefebvre, 1990; Ross & Browne, 2013; UCSF Children's Hospital, 2004).

3.6.5 Breastfeeding initiation versus breastfeeding duration

Whilst breastfeeding initiation results were broadly in line with our predictions, our breastfeeding duration (hazard of stopping breastfeeding) results were more inconsistent. This could be because duration was measured on a smaller, less representative sample, with less power to detect effects. However, we also found stronger initiation than duration results in our previous study (L.J. Brown & Sear, 2017), suggesting that initiation may be genuinely more strongly influenced by environmental quality than duration. It is likely that breastfeeding duration is more influenced by other factors such as women needing to return to work (Andrew & Harvey, 2011; Heck et al., 2006; Huang & Yang, 2015; Kimbro, 2006; Rippeyoung & Noonan, 2012). It is also interesting that Pakistani-origin mothers didn't breastfeed for longer than White British mothers in this sample, even though their initiation rates were higher. It could be that associations would be more pronounced or consistent if we had used duration of exclusive breastfeeding rather than of any breastfeeding.

3.6.6 Implications for Life History Theory

While we find some evidence for predicted associations between lower physical environmental quality and reduced breastfeeding, we also find several null associations. Moreover, the air pollution-duration and damp/mould-initiation associations amongst White British mothers suggest that investment may actually be *increased* in response to environmental risk. This could be adaptive in this low infant mortality and fertility context where replacement of infants is unlikely; it may be beneficial to invest at a higher rate and protect infants as much as possible from morbidity risk. We found some evidence for mediation by birth outcomes, suggesting that mothers may be using infant viability cues to tailor investment through breastfeeding.

The different measures of physical environmental quality support interpretations of both greater and lesser lactational investment in response to environmental stressors in our study. These mixed associations might suggest that the Bradford environment is not “harsh” enough to enforce the same maternal investment decisions mothers make in environments with greater extrinsic morbidity and mortality risk. We might expect to see more pronounced and consistent reductions where environmental adversity is greater, both in terms of the measures explored in this study and in terms of other aspects of the physical environment. Quinlan’s study exploring aspects such as famine and warfare provides good support for the life history theory prediction of reduced maternal investment in such harsher conditions (Quinlan, 2007). As well as the earlier weaning findings we mentioned in our introduction, his analysis of data from 186 pre-industrialised societies also found that maternal care was reduced in harsher conditions (Quinlan, 2007). It is also possible that forms of parental investment other than (or instead of) breastfeeding may be reduced in poorer-quality environments within high-income contexts too and this could prove a fruitful avenue for further research. Even though we found just limited support for our predictions, by using an evolutionary approach we can recognise that both biology and behaviour respond to environmental cues and that “adverse” outcomes can sometimes be understood as the result of optimising reproductive strategies in a given context. We make a theoretical contribution by showing that how environmental quality is operationalised in life history theory research is important. Our mixed findings suggest that social and economic proxies of environmental quality may be more strongly linked to life history outcomes than physical measures. Even so, associations between SEP and physical environmental quality differ by ethnic group, suggesting that SEP cannot be used as a reliable proxy for environmental exposure. This nuance cautions against using socioeconomic position, environmental quality and ethnicity interchangeably when assessing the association between environmental harshness and reproductive outcomes.

3.6.7 Limitations

We had to use data from time points as late as 4 years after birth for the two household condition indicators and to derive some breastfeeding information. For most women this would have been well after they stopped breastfeeding. We have had to assume that this exposure was the same as during pregnancy but this may not be the case for all participants. Additionally, for some indicators we only had data available for sub-cohorts, reducing our sample size for analysis but also the representativeness of our findings. For example, damp/mould exposure and lack of central heating access were both measured at least 12 months after birth and only for mothers in the ALLIN and MeDALL sub-cohorts; this might partially explain their protective and null effects, respectively, as household condition may have changed over time and the relatively smaller sample sizes may have skewed associations. A further limitation was our restricted exploration of other ethnicities due to small numbers and heterogeneity in the “other” category.

Whilst we were able to demonstrate some associations between physical environmental quality and breastfeeding outcomes, an understanding of the proximate mechanisms which drive these associations is needed to determine whether breastfeeding is causally associated with environmental quality. Data on potential physiological mechanisms would be particularly helpful, for example, measuring uptake and lactational transfer of pollutants. Whilst water DBPs have been shown to transfer to breastmilk, the amount of these chemical compounds that an infant digests will vary according to the timing of maternal exposure as well as the timing of feeds (Batterman et al., 2002), with different concentrations in the breastmilk likely affecting taste and acceptability to the infant to varying extents. Air pollution exposure may similarly alter the composition of breastmilk (Cinar, Ozdemir, Yucel, & Ucar, 2011). It is possible that some aspects of the physical environment are more perceivable than others, with for example air pollution being more detectable than the concentrations of DBPs in water. The extent to which mothers consciously detect these exposures and the extent to which they consciously adjust their breastfeeding behaviour accordingly remains to be investigated.

3.6.7 Conclusion

We hypothesised that poor physical environmental quality would either directly or indirectly negatively impact the breastfeeding chances of mothers in Bradford. Our predictions were only partially supported with the size and direction of associations varying according to environmental exposure, ethnicity and breastfeeding outcome, with little evidence for an indirect effect through neonate size. From a policy perspective, in order to improve the health of the population it is important to understand how individual attributes interact with environmental exposure to produce synergistic and modifiable effects (Erickson & Arbour, 2014). The results of our study suggest that environmental hazard exposure is not always synonymous with socioeconomic disadvantage, and that whilst the latter may be a robust predictor of lower breastfeeding chances, poor physical environmental quality has less of a consistent effect, though we did find some associations. White British and Pakistani-origin mothers had different breastfeeding and environmental experiences even though they lived in the same geographical area, additionally highlighting the importance of ethnicity, immigration and sociocultural influences. The impact of water DBP exposure on breastfeeding was particularly pronounced for the Pakistani-origin mothers in our sample and we suggest that focusing on reducing the amount of chemical compounds in water (and more research into the physiological impacts of dibromochloromethane in particular) should be a public health concern. Despite the possibility of harm from environmental contaminants in breastmilk, breastfeeding is still recommended as the safest and healthiest infant feeding method. Whilst women should be provided with personalised infant feeding support, we suggest that it is also important to focus on tackling environmental inequities in order to facilitate successful breastfeeding.

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3.9 CONFLICT OF INTEREST STATEMENT

The authors declare that they have no conflicts of interest

3.10 CONTRIBUTOR STATEMENT

LJB conceived the study and designed and conducted the analysis. Both authors were involved in the interpretation of the data. LJB wrote the initial draft of the manuscript and both authors contributed to revisions. Both authors approved the final version of the manuscript.

4. DO PARENTING, REPRODUCTIVE AND HEALTH BEHAVIOURS CLUSTER TOGETHER AS DISTINCT BEHAVIOURAL STRATEGIES? EVIDENCE FROM TWO UK COHORT STUDIES (STUDY 3)

RESEARCH PAPER COVER SHEET

PLEASE NOTE THAT A COVER SHEET MUST BE COMPLETED FOR EACH RESEARCH PAPER INCLUDED IN A THESIS.

SECTION A – Student Details

Student	Laura J Brown
Principal Supervisor	Rebecca Sear
Thesis Title	Understanding socioeconomic disparities in breastfeeding in the UK: Exploring the role of environmental quality

If the Research Paper has previously been published please complete Section B, if not please move to Section C

SECTION B – Paper already published

Where was the work published?			
When was the work published?			
If the work was published prior to registration for your research degree, give a brief rationale for its inclusion			
Have you retained the copyright for the work?*		Was the work subject to academic peer review?	

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SECTION C – Prepared for publication, but not yet published

Where is the work intended to be published?	**Demography**
Please list the paper's authors in the intended authorship order:	**Brown, L J & Sear, R**
Stage of publication	**Not yet submitted**

SECTION D – Multi-authored work

For multi-authored work, give full details of your role in the research included in the paper and in the preparation of the paper. (Attach a further sheet if necessary)	I was responsible for the research design, and conducted the statistical analysis. I was also primarily responsible for writing this work. My supervisor supported this work in an advisory capacity and helped to edit the writing.

Student Signature: [redacted] **Date:** 26/11/2018

Supervisor Signature: [redacted] **Date:** _26/11/18______

4.4 ABSTRACT

Researchers using the evolutionary framework of life history theory tend to assume that reproductive, parenting and health behaviours will pattern across a fast-slow continuum, with "fast" life histories typified by short lifespans, early maturation and investing in quantity over quality of children. These "fast" trajectories are thought to be favoured in harsher environments and/or when resources are scarce. These ideas, with different theoretical motivations, are echoed in the diverging destinies and weathering frameworks developed in the social sciences. Despite the assumption that traits across different domains cluster together, there is so far little empirical evidence to support this claim. We use data on women from two UK cohorts - the Millennium Cohort Study and the Born in Bradford study - to explore whether reproductive, parenting and health behaviours cluster into the predicted "fast" and "slow" trajectories. We further test whether similar clustering is seen in different cultural groups, by stratifying our analyses to focus on the two largest ethnic groups in both samples: White UK-born mothers and Pakistani-origin mothers.

We find some weak evidence to suggest that parenting, reproductive and health traits cluster together to reveal two distinct groups i.e. "fast" and "slow" life histories, although one of our tests suggests that splitting women into more than two classes was a better fit to the data. Whilst the life history, diverging destinies and weathering frameworks all often rely on age at first birth to distinguish women's life trajectories, we found that breastfeeding was a particularly important discriminating feature. However, health traits such as smoking and drinking did not pattern cohesively with traits in other domains. We find that Pakistani-origin mothers showed less pronounced life history strategies than the White UK-born mothers.

"Fast" life histories were predicted by greater socioeconomic disadvantage and environmental harshness across the four groups of mothers, although some indicators of adverse environments, particularly in childhood (experiencing parental death, living away from home before age 17 and exposure to air pollution) significantly reduced the chances of adopting a "fast" strategy for some. Pakistani-origin mothers also showed weaker associations with socioeconomic and environmental characteristics than White-UK born mothers.

Breastfeeding, whilst no longer necessary for infant survival in the high-income context of the UK, appears to still be a key aspect of women's parenting behaviour. Cultural constraints and differing immigration histories may explain the less pronounced life history strategies observed in the Pakistani groups.

4.5 INTRODUCTION

There is a long-standing assumption, held across several disciplines, that fertility and parental investment will be correlated. The quality-quantity trade-off assumes that parents who have many children will invest relatively less in each child, compared to parents who have fewer and can invest relatively more in each (Becker & Tomes, 1976; Colodro-Conde, Rijsdijk, & Ordoñana, 2013). There is some evidence for this trade-off, though the data are perhaps not quite as clear-cut as the widespread nature of this assumption might suggest (Lawson, Alvergne, & Gibson, 2012; Lawson & Mace, 2011). In evolutionary theory, the quality-quantity trade-off is assumed to form just one part of a correlated suite of behavioural and physiological responses to social and environmental conditions. Life history theory provides a powerful tool for explaining variation in physiology and behaviour (Nettle, 2010a; S. C. Stearns, 1992). Derived from cross-species research, and now applied *within* as well as *between* species, this evolutionary framework suggests that individuals adopt a different set of reproductive, parenting and other behaviours depending on their personal, social, and ecological conditions (Bielby et al., 2007; S. C. Stearns, 1983). One popular use of this framework divides these behaviours into "fast" and "slow" life history strategies; the former typified by for example, short lifespans, early maturation and reproduction, having several offspring and investing relatively little in each; and the latter, by slower growth and maturation, fewer children and greater parental investment in each (Wells et al., 2017).

Further, life history theory makes predictions about the circumstances under which fast or slow life histories will emerge: fast life histories will be favoured in harsh environments and/or when resources are scarce (i.e. environments in which extrinsic mortality risk is relatively high); and that slow life histories are favoured in more benign environments (where mortality risk is relatively low). While this clustering of traits into “fast” and “slow” trajectories is widely assumed, and there is between-population evidence to suggest some of the traits do cluster consistently together (B. S. Low, Parker, Hazel, & Welch, 2013), there is relatively little data which has demonstrated such clustering of traits across several domains *within* populations. Most life history studies focus on just one domain such as reproductive or somatic effort (where somatic effort refers to investment in one’s own health and survival). For example, age at first birth has been consistently shown to be earlier in ‘harsher’ environments (Cabeza de Baca & Ellis, 2017; Ellis, 2004; B. S. Low et al., 2013); harshness also predicts health behaviours which prioritise short-term reward over long-term gain, both in longitudinal data and experimentally (Pepper & Nettle, 2017; Sheehy-skeffington & Rea, 2017). Both socioeconomic and environmental conditions influence decision-making and physiological responses, resulting in nuanced differences in behavioural expression dependent on context (Griskevicius, Tybur, et al., 2011; Mittal, Griskevicius, Simpson, Sung, & Young, 2015; Pepper & Nettle, 2014b; Sheehy-skeffington & Rea, 2017).

The idea that behaviours cluster together and that they are influenced by socioecological context is not unique to evolutionary perspectives: the influential role of earlier life experiences and the importance of socioeconomic conditions are key to both life course and social epidemiology (Glymour, Avendano, & Kawachi, 2014; Halfon, Larson, Lu, Tullis, & Russ, 2014); sociologists have posited that socioeconomic and ethnic/racial disparities in resource access are the fundamental causes of health inequalities (Link & Phelan, 1995; Phelan & Link, 2005); and demographers have echoed similar logic in the weathering hypothesis (Geronimus, 1996; Geronimus, Hicken, Keene, & Bound, 2006; Goisis & Sigle-Rushton, 2014).

The weathering hypothesis posits that the health status of disadvantaged groups deteriorates in response to persistent harsh social and environmental conditions. These insults then have deleterious consequences for a woman’s health, health behaviours, and if she has a child, her infant’s health. The effects of social inequalities compound with age, leading to growing health disparities throughout adulthood (Geronimus, 1996; Geronimus et al., 2006). Although the weathering hypothesis focuses largely on health, reproductive and parenting behaviours are also intertwined, with for example, some studies exploring how ethnic variations in fertility timing may be a response to likely health deterioration in adulthood (Geronimus, 1996).

Another demographic model, “diverging destinies”, ties the domains of reproduction and parenting together, positing that the second demographic transition has resulted in women adopting one of two trajectories - one characterised by delayed childbearing and increased resources for children, and the other associated with earlier childbearing, childbearing outside of marriage, union instability and less resources for children (Kalil, Ryan, & Corey, 2012; McLanahan, 2004; Musick & Michelmore, 2018). All three frameworks – 1) life history theory, 2) the weathering hypothesis, and 3) diverging destinies, are similar in their prediction that traits cluster together, but vary in which domains they focus on. Our paper connects these frameworks by bringing the domains of parenting and reproduction together with the domain of health. From the life history perspective, a comprehensive strategy would imply clustering across several different domains, reflecting functional suites of multiple traits aiming toward short term returns in harsh conditions and/or when resources are scarce and long term returns when resources are more abundant and/or environmental quality is better. In a rare example of examining traits across more than one domain, Mell and colleagues found that coordinated health (BMI, general health status, health effort, cigarette consumption) and reproductive strategies (age at first birth and fertility) emerged in response to childhood environmental harshness (2018). We add to Mell et al.’s research by also including parental investment and union instability measures to test whether these different traits manifest as a coordinated suite of behaviours. Here we investigate whether reproductive, parenting and health behaviours cluster together.

We also test whether the behaviours that do cluster together are socioeconomically and environmentally contingent, as is predicted by life history theory, using various indicators of resource access and environmental harshness. Both the diverging destinies and life history theory frameworks emphasise that reproductive and parenting behaviours are dependent on socioeconomic status (SES). The former emphasises that trajectories are educationally contingent, whilst the latter conceptualises SES (including but not limited to education) as a marker of resource access, with low SES acting as an important constraint on behavioural responses to environmental conditions.

Although it also encompasses the effects of socioeconomic disadvantage, the weathering hypothesis borne out of US-based research, focuses primarily on racial disparities between Black and White Americans. There is more of a tradition of exploring ethnic differences in the States, because there is significant ethnic variation, and the weathering hypothesis is seldom applied outside of the US context (Sear, Lawson, Kaplan, & Shenk, 2016; but see Goisis & Sigle-Rushton, 2014). The weathering hypothesis suggests that, even apart from socioeconomic disadvantage, ethnic minorities suffer greater disadvantage because of structural racism which leads to faster weathering (Geronimus, 1996; Geronimus et al., 2006, 2016). Even though it is important to test for within-population heterogeneity in large, complex societies like the UK (Stulp, Sear, & Barrett, 2016), life history work in high-income populations has not examined ethnic or other within-population heterogeneity in fast/slow life history strategies. We address this neglected area by examining trait clustering in the two largest ethnic groups in our two samples separately.

Our Millennium Cohort Study (MCS) sample captures a representative sample of mothers from across the UK whilst our Born in Bradford (BiB) sample captures only mothers from Bradford, West Yorkshire, in England. Pakistani-origin mothers are the minority ethnic group in both of our samples. UK-wide, only about 2% of the population are of Pakistani-origin (Office for National Statistics, 2012). Even though Bradford has the largest proportion of people of Pakistani-origin in England (20.3%), they are outnumbered by the White British population by more than three to one (63.9%) (City of Bradford Metropolitan District Council, 2018). The consequent ethnic minority status of the Pakistani-origin mothers in our samples may therefore subject them to racial discrimination. The wear and tear associated with persistent exposure to the resultant acute and chronic stress may manifest as worse health outcomes and worse health behaviours.

Previous research using the Born in Bradford dataset has shown that environmental exposure to pollutants during pregnancy varies by ethnicity (L.J. Brown & Sear, 2019; R. B. Smith et al., 2016). Differing immigration histories will mean that earlier environmental conditions will also vary for the White UK-born and Pakistani-origin mothers (i.e. either born in Pakistan or parents born in Pakistan) in our samples. Both ethnic groups will be influenced by living in the UK but some of the Pakistani-origin mothers will be additionally influenced by having lived in Pakistan. Context-dependent differential environmental exposure and resource access may result in different trade-offs between traits and therefore the presentation of qualitatively different life history strategies.

Do traits still cluster in a high-income industrialised context like the UK? Are we likely to still show evolutionary legacies in our physiology and behaviour? Whilst our current environments are evolutionary novel, we still evaluate threats and resources to inform our reproductive and parenting decisions, whether consciously or otherwise. The types of threats and resources we are exposed to are of course different today than in our evolutionary past but the ability to process this information to calibrate behaviour flexibly has transferred to modern contexts. Applying an evolutionary framework, even in high-income industrialised settings such as the UK, allows us to examine associations between behaviours as potential adaptive responses (whether conscious or unconscious) to ecological constraints and opportunities (Cabeza de Baca & Ellis, 2017; Ellis, 2004; Stulp, Sear, & Barrett, 2016). Breastfeeding is closely linked to interbirth intervals through two-way physiological regulation and is the main method of fertility regulation in traditional societies (Bongaarts, 1978; Colodro-Conde et al., 2013). Breastfeeding and interbirth intervals are however likely to become disengaged in contexts such as the UK, where contraceptive use is widespread (Howie & Mcneilly, 1982; Milne & Judge, 2012). Widespread contraceptive use may also decouple age at first sex from age at first birth. Reproductive traits that occur before conception, such as the onset of puberty, may be more reliable indicators of later reproductive and parenting behaviour in modern contexts as these will not be affected by contraceptive use (Milne & Judge, 2012). The increased time between sexual maturation and age at first birth as women place more emphasis on resource acquisition is another example of modern society severing expected links between reproductive behaviours (Myrskylä, Barclay, & Goisis, 2017). The extent to which different parental investment behaviours relate to one another, and the extent to which they relate to other aspects of reproduction in high-income contexts like the UK is unclear. Identifying “at-risk” populations is important from a policy perspective (Caspi et al., 2016), as acknowledged in the diverging destinies framework (McLanahan, 2004). There is therefore a need to assess the extent to which reproductive, parenting and health behaviours are associated with one another and also whether clustering differs by ethnicity. In other words, to what extent do destinies really diverge?

4.5.2 Aims and predictions

We conduct latent class analysis on data from the UK's Millennium Cohort Study and Born in Bradford study to empirically test the extent of trait clustering across different behavioural domains in UK mothers. We add to the existing literature by 1) including several domains of behaviour, and 2) examining whether there are any ethnic differences in either clustering of traits or associations between socioeconomic/environmental conditions and life history strategy. Specifically, we:

1) test whether UK mothers readily split into two life history strategies;
2) assess the extent of clustering between and within the behavioural domains of parenting, reproduction and health; and
3) test whether strategies are socioeconomically and environmentally patterned.

4.6 METHODS

4.6.2 Samples

The two datasets we use, although both from the UK, have different geographical focuses. The Millennium Cohort Study (MCS) is a nationally-representative ongoing longitudinal study following the lives of around 19,000 children born in the UK between 2000 and 2002 (for a more detailed cohort profile see Connelly & Platt, 2014; UCL Centre for Longitudinal Studies, 2015c) whilst the Born in Bradford study (BiB) follows the health and wellbeing of over 13,500 children born at the Bradford Royal Infirmary, West Yorkshire, England between March 2007 and December 2010 (for cohort profile see Wright et al., 2013). It is important to note that this is a study of mothers, rather than all women, as we focus on the life histories of the cohort members' mothers rather than of the cohort members themselves. We weight the MCS data where possible to account for the complex survey design and increase generalisability of our results. The BiB data does not need to be weighted due to the simpler sample design and limited geographical focus.

As well as only including the two largest ethnic groups in both samples, we further restricted analyses to cases where the main respondent was the natural mother and still living with the focal child. We excluded still births and multiple births. These restrictions left us with maximum usable sample sizes of 12,575 (weighted n=13,246) White UK-born mothers and 712 (weighted n=496) Pakistani-origin mothers in the MCS and 3,938 White British mothers and 4,352 Pakistani-origin mothers in the BiB. For the MCS sample, we combined information from Waves 1 and 2, when the cohort children were 9 months and 3 years old, respectively. For the BiB sample, we combined information from the baseline questionnaire (26-28 weeks gestation), the maternity information system (mainly covering information collected at birth) and sub-cohort follow-up surveys (BiB1000, ALLIN (ALLergy and INfection) and MeDALL (MEchanism of the Development of ALLergy)). We draw on information collected at different time points, ranging from when the cohort child was 6 months old through to 4 years old. Our sample sizes vary depending on which variables are included in our analyses as not all MCS mothers completed both survey waves and not all BiB mothers participated in the sub-cohorts.

4.6.3 Life history trait indicators

We chose a range of variables from both our datasets, selecting those that could capture parenting, reproductive, and health behaviour comprehensively. Where possible, we chose comparable variables and constructed indicators in the same way for the MCS and BiB samples. Where more than one candidate variable was available, we chose the variable that we felt best captured the trait in question. For example, we chose self-rated general health in the MCS over whether the mother had a longstanding illness, disability or infirmity because it captures a broader spectrum of health. Within the parenting domain, we indexed prenatal investment with a variable combining birthweight and gestational age and indexed postnatal investment with breastfeeding initiation and duration, as well as whether the mother took the child to activities regularly (BiB only), expressed affection towards them regularly, how often she read to them and how many routine vaccinations were given. These indicators were chosen to encompass parental investment of differing types. Values indicative of lower parental investment e.g. not breastfeeding and shorter durations of breastfeeding, not vaccinating, and not reading to the child often were considered “fast” behaviours. Within the reproductive domain, we included age at menarche (BiB only), age at cohabitation/marriage (MCS only), age at first birth, parity and union stability. Ages were in years, and earlier ages reflect faster strategies. Parity was split into high and low and union stability was indexed by whether the mother was still living with the cohort member’s father at the time of the last survey. The reproductive domain therefore captured reproductive timing, effort and output. In order to index investment in self, we used a mix of health outcomes and behaviours within the health domain: general health in the MCS and poor mental health in BiB, and smoking, drinking and bodyweight in both datasets. Across the three domains most of the indicators were scored so that higher values indicated “slower” traits. The exceptions were union instability (0 = mother still living with child’s father; 1 = no longer living with the child’s father), parity (0 = <4 children; 1 = ≥4 children), general health (1 = excellent; 2 = good; 3 = fair; 4 = poor), poor mental health (0 = <75th centile of general health questionnaire scores; and 1 = ≥75th centile), ever regularly smoked (0 = No; 1 = Yes) and drinks alcohol (0 = No; 1 = Yes). Further details on the selected variables and how indicators were derived and constructed are provided in Table C.1 in Appendix C.

4.6.4 Analysis

4.6.4.1 Classifying and characterising life history strategies

We first tested for correlations between life history traits in each of our four groups. We then used latent class analysis with maximum likelihood estimation to test whether each of the four groups of mothers could be split into two classes with distinct patterns of life history traits i.e. into “fast” and “slow” strategies. Latent class analysis (also known as latent profile analysis) uses a categorical latent variable to capture the possibility that different response profiles arise because there are underlying subgroups of individuals with distinct combinations of features (Hallquist & Wright, 2014). In this case we used it to assess whether our four groups of mothers could be split into distinct “fast” and “slow” strategists.

We assessed whether the theoretically-predicted two classes was an appropriate categorisation of the four groups of mothers by comparing two class models to models with one, three, four and five classes and examining statistical model selection criteria including model fit and neatness of classification. We also compared the estimated probabilities for categorical variables and estimated means for continuous variables for two class and then three class models, examining whether the classes differed qualitatively or quantitatively. To do so, we looked to see whether the models split mothers into distinct response profiles indicative of phenotypically different groupings, with for example one class being defined by pronounced means and probabilities of indicators in one trait domain, but otherwise showing similar means and probabilities to the other class(es) in the other domains (this would be a qualitative difference), or whether the classes just primarily differed in their mean levels across traits (a quantitative difference). The three class model was used to ascertain whether introducing a third class would effectively create a middling group, or whether more qualitative differences would emerge with the classes having different key distinguishing features, with for example one group scoring fast on parental investment indicators and a different group scoring fast on reproductive timing. We also performed sensitivity analyses, details of which are presented in the Supplementary Material.

We used Akaike's information criterion (AIC) and Bayesian Information Criterion (BIC) as measures of relative goodness of fit, where lower values indicate better fit. We used normalised entropy to measure classification quality. Its values range from 0 to 1, with values closer to 1 indicating greater class separation (Ng & Schechter, 2017; Silverwood, Nitsch, Pierce, Kuh, & Mishra, 2011).

4.6.4.2 Predicting life history strategy with socioeconomic and environmental characteristics

We then used class membership predicted from the two class models as the outcome in regression models to test whether fast strategy membership was predicted by resource access and extrinsic risk as is predicted by life history theory. Mothers were assigned fast or slow life history strategies based on their predicted probabilities of being in each of the two classes; mothers whose probability of being in the fast class was greater than their probability of being in the slow class were therefore categorised as fast, and vice versa.

Our choice of environmental harshness indicators was informed by our prior research looking at links between environmental quality and breastfeeding in both datasets (L.J. Brown & Sear, 2017, 2019). We used two summary measures of local environmental conditions (street and neighbourhood level) to predict life history strategy membership in the MCS sample. One of these captures subjective environmental experience and the other reflects objective environmental evaluation with the former derived from mothers' own reports of their environment, and the latter from an independent neighbourhood assessment (more details on these measures including factor analysis loadings can be found in Brown & Sear, 2017).

Building on our previous research linking the physical environment to breastfeeding in the BiB study (L.J. Brown & Sear, 2019), we included measures of water disinfectant by-product exposure, air pollution, passive smoke exposure, and household condition. Due to a predominant emphasis on the importance of early life environmental circumstances in life history theory research, we also regressed life history strategy on two indicators of childhood environmental harshness in the MCS groups: 1) parental separation/divorce during childhood and 2) living away from home before age 17. Whilst there was more specific information about the place where those who did live away from home lived, we just used the binary indicator as we were interested in disruptive childhood experience and lack of parental investment generally, rather than women's experiences in different institutions. We also indexed the availability of social support by looking at whether the mother's parents were still alive. Whilst there were other support measures available, such as whether the mothers had other parents to talk to and whether they sought support since birth, we were particularly interested in the availability of familial support, a key driver of age at reproduction and fertility (Geronimus, 1997; Rebecca Sear, 2018). There were no comparable childhood harshness or parental death indicators available in the BiB dataset.

We operationalised socioeconomic position as a standardised score of socioeconomic disadvantage, where positive scores reflect higher than average socioeconomic disadvantage and negative scores reflect lower than average socioeconomic disadvantage (i.e. more advantage). This is a latent variable based on job status, education, how well managing financially and receipt of means-tested benefits in both the MCS and BiB samples, and additionally on income in the MCS and food security in BiB study. We also included the Index of Multiple Deprivation (IMD) to capture area-level socioeconomic disadvantage, using deciles for the MCS and quintiles for BiB.

We conducted several separate unadjusted logistic regression analyses to test whether socioeconomic disadvantage and environmental harshness were associated with strategy membership, using the "slow" strategy as the reference class. We also included all of the socioeconomic disadvantage and environmental harshness predictors in the same model to see whether any of the associations remained after other influences were controlled for. All models adjusted for clustering at the ward level and the MCS models additionally adjusted for survey stratification and the focus on specific subpopulations.

Analyses were conducted in Stata 15.1 using the structural equation modelling framework's recent latent class expansion (StataCorp, n.d.).

4.7 RESULTS

4.7.2 Classifying and characterising life history strategies

Tables 4.1 and 4.2 show the polychoric correlations between life history indicators for the MCS and BiB samples, respectively. Looking first just at directions of association, within the domain of parenting between 50% (BiB Pakistani-origin mothers) and 71.4% (MCS White UK-born mothers) of estimable correlations were in the predicted direction. For reproduction, the range was between 40% (MCS Pakistani-origin mothers) and 80% (MCS White UK-born mothers). Whilst the MCS White UK-born mothers showed the most correlations within the domains of parenting and reproduction, they showed the least within the health domain of the four groups (33.3%); MCS Pakistani-origin mothers showed the most correlations in this domain (83.3%). The correlations within domains were however mostly pretty weak. Age at cohabitation/marriage's positive association with age at first birth in the MCS was the exception, with strong correlations of (>0.700) in both groups. Correlations were at best modest between parenting indicators, with reading frequency and breastfeeding duration in BiB White British mothers having the strongest correlation in this domain across the four groups (0.419). Correlations were also generally weak in the health domain, although smoking and drinking were moderately positively correlated in BiB Pakistani-origin mothers (0.509).

The BiB White British mothers showed the most clustering *between* domains as is indicated by the proportion of correlations in the predicted direction (65.3%) whilst the MCS Pakistani-origin mothers showed the least (50.8%). As with the within-domain correlations, most correlations between domains were weak. Reading frequency and drinking alcohol were however strongly correlated amongst BiB Pakistani-origin mothers (-0.936). The strongest inter-domain correlations in the other groups were between age at first birth and breastfeeding initiation amongst White mothers in both the MCS (0.403) and BiB (0.389), and between expressing affection and smoking amongst MCS Pakistani-origin mothers (-0.390).

Overall then, most correlations both within and between trait domains were weak. Whilst on the whole the two White UK-born groups showed more trait clustering than the two Pakistani-origin groups, both the direction and strength of correlations showed non-negligible variation by ethnic group and sample. Tables 4.1 and 4.2 therefore only provide weak evidence for trait clustering.

Goodness of fit statistics and entropy values for the models with one to five latent classes by sample and ethnic group are shown in Table 4.3. Whilst the AIC and BIC values indicated that model fit improved with the addition of more classes, the change in these values between models was relatively small. The MCS Pakistani-origin and BiB White British five class models did not converge, indicating that models with more latent classes did not necessarily fit the data better. Only the BiB Pakistani-origin models needed parameters constrained due to having probabilities very close to 0 or 1. Entropy values showed that the two class model had the clearest class separation for the MCS White UK-born mothers and the BiB White British mothers, whereas the four and three class models had the clearest class separation for the Pakistani-origin mothers in the MCS and BiB, respectively. Overall, these model fit comparisons suggest that two class models may be sufficient, especially for White UK-born mothers, but the evidence is not overwhelming.

Figure 4.1 shows the two class model predicted probabilities of being fast. Peaks at 0 and 1 in all four groups show that mothers split relatively well into two classes. Across the four groups, 9-30% of mothers had a probability of 0.95+ of being in the fast class and 18-28% of mothers had a probability of 0.95+ of being in the slow class. In both samples, the separation of White UK-born mothers into two classes was more clear-cut than the separation of Pakistani-origin mothers. Whilst we could confidently assign mothers near the extremes of the distribution to fast or slow, there were also non-negligible proportions with borderline probabilities. With that caveat, we proceeded with 0.5 as the cut-off for class membership, and looked to the patterning of response profiles by class to further assess the extent of trait clustering.

Table 4.1: Correlations between life history traits (MCS)

	Breastfeeding initiation [b]	Breastfeeding duration [c]	Affection expressed regularly [b]	Reading frequency [o]	Vaccinations given [o]	Child born at term and normal weight [b]	Age at cohabitation/ marriage [c]	Age at first birth [c]	Parity 4+ [a b]	No longer living with child's father [a b]	General health [a o]	Ever smoked regularly [a b]	Drinks alcohol [a b]	Bodyweight [c]
Breastfeeding initiation [b]		.	-0.049	0.072	-0.065	0.050	0.042	0.213	-0.100	-0.116	0.114	**0.397**	-0.103	-0.075
Breastfeeding duration [c]	0.000		-0.152	-0.014	.	0.021	0.128	0.235	-0.125	-0.039	-0.120	0.157	0.162	-0.052
Affection expressed regularly [b]	0.194	0.188		0.013	.	**-0.280**	0.238	-0.015	-0.129	0.086	0.129	**-0.390**	0.003	-0.049
Reading frequency [o]	**0.307**	0.197	0.201		.	0.065	0.046	0.072	-0.037	0.084	-0.088	0.215	0.257	-0.041
Vaccinations given [o]	-0.208	**-0.321**	.	-0.298		**0.322**	0.053	0.007	0.082	0.033	-0.267	0.187	-0.135	-0.036
Child born at term and normal weight [b]	0.067	0.162	0.084	0.018	-0.057		-0.001	0.090	0.341	-0.109	-0.130	0.169	0.128	0.134
Age at cohabitation/marriage [c]	0.218	0.102	0.121	0.140	-0.135	-0.008		**0.877**	-0.070	**0.028**	-0.022	0.049	0.235	-0.015
Age at first birth [c]	**0.403**	0.223	0.231	0.259	**-0.258**	0.016	**0.793**		.	0.012	-0.118	0.184	0.215	0.187
Parity 4+ [a b]	-0.147	0.048	0.006	-0.248	0.008	-0.002	**0.039**	.		-0.022	0.093	-0.246	.	0.254
No longer living with child's father [a b]	-0.297	-0.209	-0.140	-0.232	0.097	-0.079	-0.245	-0.539	0.090		0.073	0.041	0.389	0.005
General health [a o]	-0.121	-0.168	-0.235	-0.199	-0.132	-0.128	-0.044	-0.154	0.115	0.192		0.005	-0.017	**0.097**
Ever smoked regularly [a b]	0.063	0.061	0.004	0.011	-0.082	-0.027	0.037	0.086	0.090	-0.016	0.087		0.072	**-0.177**
Drinks alcohol [a b]	0.193	0.162	0.117	0.087	-0.258	0.109	0.079	0.122	-0.188	-0.096	**-0.103**	**0.124**		-0.043
Bodyweight [c]	0.039	-0.083	0.026	0.010	-0.072	0.065	0.037	0.175	0.049	-0.102	0.085	0.053	0.005	

Strong correlation against predicted direction — *No correlation* — *Strong correlation in predicted direction*

Correlations between life history indicators in the MCS, adjusted for clustering at the ward level and weighted but not stratified (as fully adjusting for complex survey design is not possible with the polychoric command). [a] Variables for which higher values indicate "fast" traits. Polychoric correlations calculated for combinations of binary ([b]) and/or ordinal ([o]) variables, polyserial correlations calculated for combinations of continuous ([c]) and binary/ordinal variables, Pearson's correlations calculated for combinations of continuous variables. Data for White UK-born mothers shown below the diagonal and Pakistani-origin mothers above the diagonal. Boxed-in areas indicate correlations between life history indicators within the same domain. Strongest correlations within and between domains shown in bold for each sample.

Table 4.2: Correlations between life history traits (BiB)

	Breastfeeding initiation [b]	Breastfeeding duration [c]	Takes child to activities regularly [b]	Affection expressed regularly [b]	Reading frequency [o]	Vaccinations given [o]	Child born at term and normal weight [b]	Age at menarche [c]	Age at first birth [c]	Parity 4+ [a b]	No longer living with child's father [a b]	Poor mental health [a b]	Ever smoked regularly [a b]	Drinks alcohol [a b]	Bodyweight [c]
Breastfeeding initiation [b]		.	0.062	-0.120	-0.044	0.032	0.067	-0.002	0.071	-0.005	-0.071	0.047	-0.076	0.064	-0.044
Breastfeeding duration [c]	.		0.055	-0.083	0.105	0.026	0.074	-0.001	0.111	0.013	0.017	0.031	-0.117	-0.484	-0.026
Takes child to activities regularly [b]	0.315	0.125		**0.140**	-0.119	-0.071	-0.085	0.020	0.100	-0.130	0.070	-0.001	0.105	.	-0.071
Affection expressed regularly [b]	0.138	-0.032	-0.016		**-0.178**	0.073	0.085	-0.018	0.150	-0.020	-0.022	0.014	0.127	.	-0.075
Reading frequency [o]	-0.226	**0.419**	0.292	0.092		-0.079	-0.019	-0.040	-0.164	0.012	0.024	0.111	0.091	**-0.936**	0.117
Vaccinations given [o]	0.117	0.062	0.152	-0.120	**-0.255**		-0.022	0.016	0.123	-0.086	-0.024	-0.001	-0.153	.	-0.005
Child born at term and normal weight [b]	0.013	0.043	0.010	-0.055	0.045	-0.072		-0.017	-0.023	0.084	-0.063	-0.005	-0.106	-0.058	0.082
Age at menarche [c]	-0.012	0.025	0.031	0.033	0.063	-0.040	0.011		0.025	0.005	-0.042	0.015	-0.050	-0.010	-0.127
Age at first birth [c]	**0.389**	0.184	0.261	0.308	-0.089	0.096	-0.043	0.061		.	**-0.195**	0.026	-0.097	-0.271	0.099
Parity 4+ [a b]	-0.076	0.045	-0.183	0.072	-0.152	-0.086	0.077	0.014	.		**-0.142**	0.132	-0.039	-0.119	**0.265**
No longer living with child's father [a b]	-0.308	-0.075	-0.209	-0.093	**0.319**	-0.070	-0.026	-0.003	**-0.511**	**-0.057**		0.171	0.256	0.312	-0.003
Poor mental health [a b]	-0.001	-0.080	-0.091	-0.041	0.061	-0.155	-0.047	-0.076	-0.073	0.020	0.130		0.143	-0.033	0.031
Ever smoked regularly [a b]	-0.188	-0.024	-0.289	-0.034	0.132	-0.131	-0.093	-0.038	-0.207	0.081	0.248	**0.152**		**0.509**	**0.064**
Drinks alcohol [a b]	0.108	0.062	-0.034	-0.135	-0.026	0.002	0.002	0.005	0.158	-0.109	-0.073	0.049	0.077		-0.155
Bodyweight [c]	-0.001	-0.070	-0.021	0.377	0.004	-0.019	0.115	-0.118	0.246	0.085	-0.142	**0.070**	-0.019	0.018	

Strong correlation against predicted direction — *No correlation* — *Strong correlation in predicted direction*

Correlations between life history indicators in BiB, adjusted for clustering at the ward level. [a] Variables for which higher values indicate "fast" traits. Polychoric correlations calculated for combinations of binary ([b]) and/or ordinal ([o]) variables, polyserial correlations calculated for combinations of continuous ([c]) and binary/ordinal variables, Pearson's correlations calculated for combinations of continuous variables. Data for White British mothers shown below the diagonal and Pakistani-origin mothers above the diagonal. Boxed-in areas indicate correlations between life history indicators within the same domain. Strongest correlations within and between domains shown in bold for each sample.

Table 4.3: Statistical criteria for latent class models with 1-5 latent classes by sample and group

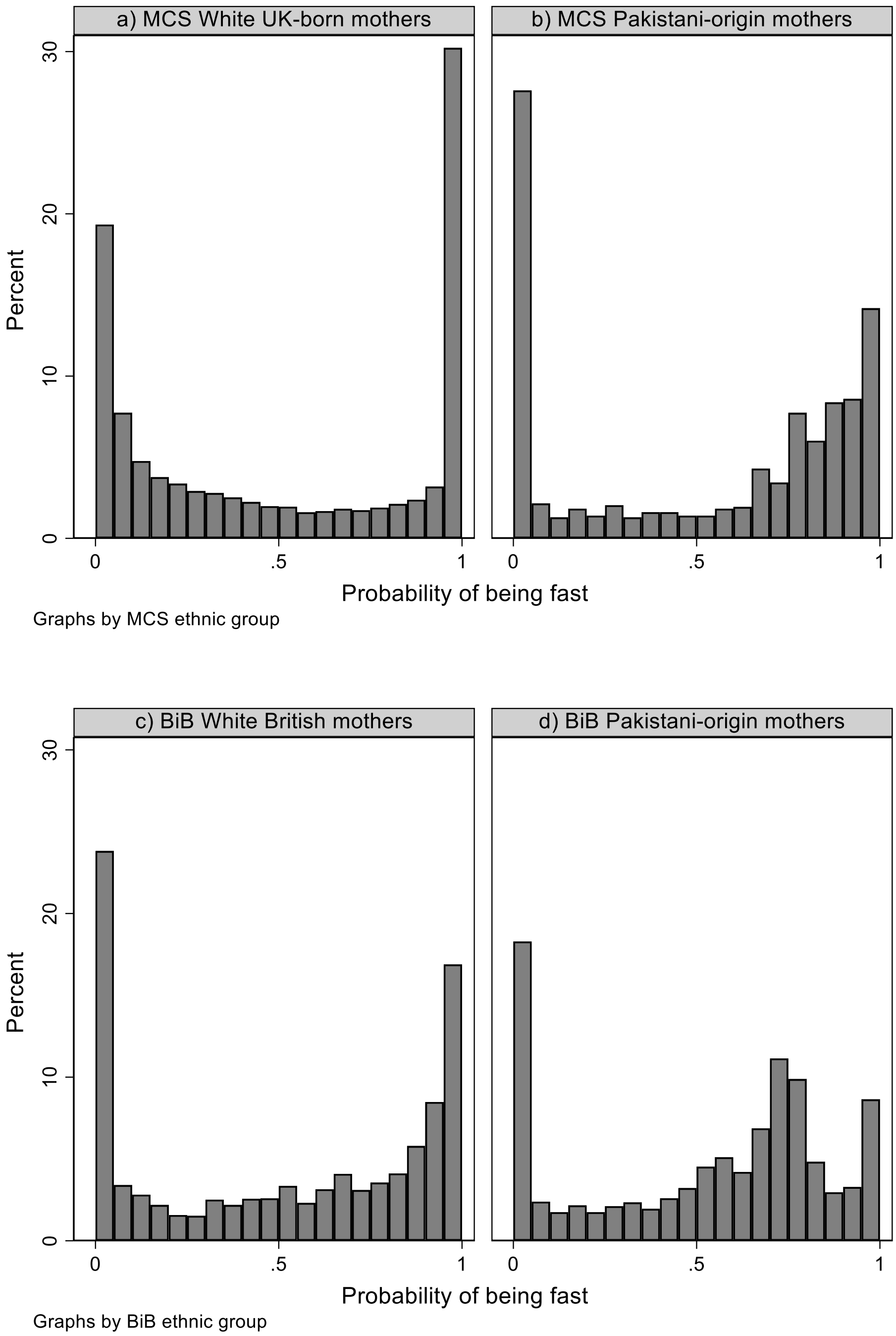
	MCS[a]						BiB					
# of	White UK-born mothers (n=14,840)			Pakistani-origin mothers (n=931[b])			White British mothers (n=3,937)			Pakistani-origin mothers (n=4,351[c])		
classes	AIC	BIC	Entropy	AIC	BIC	Entropy	AIC	BIC	Entropy	AIC	BIC	Entropy
1	428434.81	428647.75	.	13168.24	13293.98	.	97525.77	97695.28	.	95979.39	96151.60	.
2	418201.05	418634.54	**0.627**	12825.62	13081.94	0.609	95745.17	96015.13	**0.459**	94694.33	94885.67	0.431
3	414768.88	415422.91	0.601	12749.24	13111.96	0.578	94925.46	95201.70	0.453	94181.14	94378.86	**0.496**
4	411903.53	412778.11	0.625	**12622.52**	**12990.07**	**0.716**	**94515.34**	**94791.58**	0.442	93807.16	94004.88	0.438
5	**410732.06**	**411827.19**	0.599	.	.	.	.	.	.	**93604.75**	**93796.09**	0.442

[a] MCS models not full adjusted for complex survey design as survey setting does not permit goodness-of-fit statistics, ns are therefore unweighted. [b] Vaccination variable omitted from MCS Pakistani-origin models due to small cell sizes. [c] alcohol consumption constrained to be -15 for Class 3 in the three class model, for Class 4 in the four class model, and for both Class 4 and Class 5 in the five class model. Best fit and class separation statistics highlighted in bold for each sample. AIC=Akaike Information Criterion; BIC=Bayesian Information Criterion.

4.7.2.1 Profiles of “fast” and “slow” mothers in the two class models

Taking the two class models forward, values in Table 4.4 represent response profiles by sample, group and class. Probabilities of experiencing a given trait (for binary indicators) or trait category (for ordinal indicators) are shown along with class means (for continuous indicators). The classes were of similar relative size in the four groups, with each class representing about half of each group. In each group the class with the most questionnaire responses indicative of “fast” behaviour was labelled “fast” and the other class was labelled “slow”. None of the groups split so that all life history traits were faster in one class than the other, although each group only had a maximum of two indicators with significantly “faster” estimates in the “slow” class. These divergent indicators fell mostly within the health domain, e.g. chances of alcohol consumption were significantly higher in the “slow” class of both White UK-born groups, chances of having ever smoked regularly were (non-significantly) higher in both “slow” classes in the MCS, and the “slow” Pakistani-origin mothers had (non-significantly) worse general health in the MCS and worse mental health in the BiB than their “fast” counterparts. In addition, reproduction indicators clustered separately from the other domains in BiB Pakistani-origin mothers with the “fast” class generally having lower levels of investment in parenting and health, but the “slow” class having the earlier age at menarche and higher chances of having at least four children. The fast and slow classes largely differed quantitatively rather than qualitatively then, with classes primarily differing just in mean levels and probabilities across traits, rather than for example, one class being defined by indicators in one trait domain.

Figure 4.1: Fast strategy probability distributions



Two class model predicted probabilities of being in the "fast" class by sample and ethnic group. Mothers with probabilities <0.5 were categorised as "slow" and mothers with probabilities ≥0.5 were categorised as "fast". a) n=14,840, b) n=931, c) n=3,938, d) n=4,352.

Table 4.4: Response profiles by sample, group and class: 2 class models

	MCS				BiB			
	White UK-born mothers (n=12,647)		Pakistani-origin mothers (n=712)		White British mothers (n=3,937)		Pakistani-origin mothers (n=4,351)	
	Entropy=0.612		Entropy=0.627		Entropy=0.459		Entropy=0.431	
	Fast (45%)	Slow (55%)	Fast (52%)	Slow (48%)	Fast (51%)	Slow (49%)	Fast (52%)	Slow (48%)
Parenting								
Breastfeeding initiation	**0.49**	0.87	***0.70***	0.83	**0.21**	0.63	***0.55***	0.59
Breastfeeding duration (months)	**0.40**	3.94	**0.59**	3.81	**0.76**	11.17	**2.62**	13.88
Takes child to activities regularly					**0.49**	0.76	0.49	***0.48***
Expresses affection towards child regularly	**0.93**	0.98	0.89	***0.88***	***0.93***	0.95	0.88	***0.84***
Reads to child:								
Not very often	**0.31**	0.09	***0.45***	0.44	0.79	***0.84***	***0.65***	0.58
Quite often	**0.21**	0.17	0.20	***0.21***	**0.13**	0.05	***0.26***	0.24
Very often	**0.48**	0.74	0.36	***0.35***	**0.09**	0.11	***0.08***	0.18
Routine vaccinations given to child [a]:								
None	0.00	***0.00***			**0.18**	0.09	0.08	***0.12***
Some	1.00	***1.00***			***0.59***	0.63	0.62	***0.58***
All					***0.24***	0.28	***0.29***	0.30
Child born normal birthweight and at term	**0.90**	0.93	***0.83***	0.86	***0.92***	0.93	***0.88***	0.91
Reproduction								
Age at menarche (years)					***13.03***	13.05	13.59	**13.27**
Age at cohabitation/marriage (years)	**22.42**	25.37	**20.17**	21.99				
Age at first birth (years)	**23.60**	29.75	**21.37**	25.43	**21.02**	28.88	***24.82***	24.93
Parity 4+	**0.08**	0.05	0.18	***0.18***	**0.12**	0.08	0.16	**0.33**
No longer living with child's father	**0.34**	0.09	***0.11***	0.08	**0.47**	0.13	***0.08***	0.06
Health								
Poor mental health					**0.31**	0.23	0.29	***0.33***
General health:								
Excellent	**0.11**	0.26	***0.10***	0.10				
Good	***0.55***	0.57	0.53	***0.49***				
Fair	**0.28**	0.15	0.30	***0.31***				
Poor	**0.07**	0.03	0.08	***0.11***				
Ever smoked regularly	0.21	***0.22***	0.01	***0.02***	**0.69**	0.47	***0.09***	0.08
Drinks alcohol	0.90	**0.96**	0.03	***0.04***	0.63	**0.75**	***0.01***	0.00
Bodyweight (kgs)	65.09	***63.23***	**57.16**	64.06	72.58	***71.20***	**59.71**	71.20

Estimated probabilities for categorical indicators and estimated means for continuous indicators; continuous indicators are those with units in brackets. "Faster" values for each trait highlighted in bold for each sample and italicised where confidence intervals overlapped with the other class in the sample. [a] Vaccinations excluded from MCS Pakistani-origin model due to small cell counts.

Looking across samples and ethnic groups at particular indicators, we can see that the extent to which the probability/mean estimates for the fast class differed from the slow class varied substantially across indicators, ethnic groups and datasets. For example, in some cases the absolute differences between class probability estimates were negligible, with estimates so close that at 2 decimal places they were equivalent (e.g. vaccinations in MCS White UK-born mothers and parity and excellent general health in MCS Pakistani-origin mothers). At the other extreme, "fast" BiB White British mothers were 1.8 times less likely to initiate breastfeeding compared to “slow” mothers in the same group (an absolute difference of 38 percentage points). Age at first birth also differed quite dramatically across the classes for White mothers but not Pakistani mothers. Breastfeeding emerged as a particularly strong determinant of life history strategy, with the fast class having significantly lower chances of initiation amongst White UK-born mothers and significantly shorter breastfeeding durations in all four groups. None of the other common indicators showed consistent significant differences across classes for all four groups of mothers. However, if we just look at trends (ignoring whether differences between the classes were significant), breastfeeding initiation also patterned consistently across the four groups in the predicted direction, as did age at first birth, prenatal parental investment and union stability. The fast women in each sample had lower probabilities of having a normal birthweight and term baby, but only significantly so in the MCS White sample. The probability of no longer living with the cohort child’s father was a significant determinant of fast class membership for White UK-born mothers; Pakistani mothers showed the same trends although the class differences were non-significant.

Reproductive traits all patterned in the same direction in White mothers, with earlier age at first birth and higher parities in the fast classes in both groups, earlier age at cohabitation/marriage in the MCS White group and (non-significantly) lower age at menarche in the BiB White group. There was less clustering of reproductive traits amongst Pakistani mothers however, with the MCS fast class having earlier ages at cohabitation/marriage and first birth but parity chances similar to the slow class, and the BiB fast class having significantly *later* menarche and *lower* parity and an age at first birth similar to the slow class.

4.7.2.2 Profiles in 3 class models

When mothers were split into three classes instead of two, qualitative differences began to emerge and it was difficult to nominate one class as definitively “faster” than the others (Table C.7 in Appendix C). Some of the indicators did however show a clear gradient of probabilities across the classes, with the three estimates being significantly different from one another. The MCS White UK-born mothers showed the most significant gradients of the four groups. The two White groups split quite similarly into three classes with one class exhibiting significantly less parental investment, earlier reproductive timing and higher chances of union instability, another class exhibiting significantly more parental investment, lower chances of union instability, and later reproductive timing, with the remaining class middling in these traits. Breastfeeding and age at first birth were particularly discriminant indicators of these differences. As with the two class models, classes did not split so cohesively by health indicators. The BiB Pakistani mothers showed fewer distinct gradients, with age at first birth, parity and bodyweight patterning in different directions. There were no significant gradients in the MCS Pakistani mothers.

4.7.3 Predicting life history strategy with socioeconomic and environmental characteristics

Tables 4.5 and 4.6 show the distribution of socioeconomic and environmental characteristics by latent class (fast or slow), sample and ethnic group and Tables 4.7 and 4.8 show the results from the regression models predicting class membership by environmental and socioeconomic variables.

If we assume that our splitting of mothers into two distinct classes based on life history traits is correct, then we would expect to see class membership predicted by socioeconomic and environmental characteristics, with greater disadvantage and harshness being associated with an increase in life history speed i.e. greater odds of being in the "fast" class. Given the importance of environmental risk and resource access in patterning human behaviour, we would also expect the same direction of association across different socioeconomic and environmental indicators and across both samples and all four groups. The regression results largely support the notion that life history strategy is socioeconomically and environmentally patterned, although this is supported to varying degrees across the four groups of mothers.

The socioeconomic disadvantage score and area-level deprivation quantiles, although derived differently in the two studies, were the most comparable indicators that we had across the four groups (as the environmental harshness indicators were study-specific). Both of these resource access indicators significantly predicted life history strategy in the predicted direction in the White groups but only area-level deprivation was a significant positive predictor of fast strategy in the Pakistani groups, and only in the MCS. Both groups of BiB mothers showed increased odds of being fast with increased environmental harshness, regardless of how this was operationalised (i.e. all associations were in the predicted direction, albeit not all significantly). White British mothers still showed increased odds for three out of five indicators in the adjusted model, and Pakistani mothers four. In contrast, not all environmental indicators patterned in the predicted direction in the MCS unadjusted models, and each ethnic group only showed increased odds for two out of five environmental indicators in adjusted models. Of note, parental death remained significantly protective against adopting a fast strategy amongst the White UK-born mothers and living away from home became protective after model adjustment. None of the four groups had all five of their environmental harshness indicators pattern in the same direction in adjusted models, but the Pakistani groups had less significant associations (regardless of direction) compared to the White groups.

Regression results were similar for the two MCS groups - only childhood environment indicators patterned in different directions in the two ethnic groups in unadjusted models, and only objective environmental harshness patterned in different directions in the adjusted models. Regression results were also similar for the two BiB groups, with area-level deprivation, water chlorination, passive smoke and central heating access patterning in the predicted direction in both unadjusted and adjusted models for both ethnic groups (socioeconomic disadvantage also patterned in the predicted direction for both groups but in the adjusted model only). The odds of being fast increased non-significantly with greater air pollution in both ethnic groups but the direction of association changed once the other socioeconomic/environmental influences were accounted for, with White British mothers having significantly lower odds of adopting a fast life history strategy with increased pollution exposure.

Area-level deprivation amongst MCS White UK-born mothers (most vs least deprived OR: 12.12) and amongst MCS Pakistani-origin mothers (third most vs least deprived OR: 6.84) showed the largest significant effects on life history strategy in the predicted

Table 4.5: Socioeconomic and environmental characteristics by ethnicity and life history class (MCS)

	White UK-born mothers		Pakistani-origin mothers	
	Fast	Slow	Fast	Slow
Socioeconomic disadvantage score [a]	0.37 (±0.02)***	-0.59 (±0.03)	0.73 (±0.07)**	0.49 (±0.10)
n	*6,322*	*6,924*	*279*	*217*
Education (highest family qualification level)	***		***	
None	903 (14.3%)	145 (2.1%)	99 (35.3%)	68 (31.4%)
Level 1 or 2	2,589 (41.0%)	1,277 (18.5%)	87 (31.3%)	47 (21.5%)
Levels 3 to 5 (inc. other and overseas)	1,706 (27.0%)	1,832 (26.5%)	60 (21.6%)	48 (22.3%)
Level 6 plus	1,123 (17.8%)	3,669 (53.0%)	33 (11.8%)	54 (24.8%)
Job status (highest family NS-SEC)	***			
Higher managerial, administrative and professional	1,574 (24.9%)	4,385 (63.3%)	31 (11.1%)	43 (19.8%)
Intermediate	1,259 (19.9%)	1,257 (18.2%)	58 (20.8%)	46 (21.0%)
Routine and manual	2,905 (45.9%)	1,132 (16.4%)	123 (44.1%)	75 (34.7%)
Not applicable	585 (9.3%)	150 (2.2%)	67 (24.1%)	53 (24.5%)
Income (equivalised quintiles)	***		*	
1 - Lowest	1,976 (31.3%)	501 (7.2%)	137 (49.0%)	82 (38.0%)
2	1,622 (25.7%)	903 (13.1%)	109 (39.1%)	83 (38.2%)
3 - Middle	1,321 (20.9%)	1,401 (20.2%)	15 (5.4%)	28 (12.9%)
4	890 (14.1%)	1,902 (27.5%)	11 (3.9%)	9 (4.3%)
5 - Highest	513 (8.1%)	2,215 (32.0%)	7 (2.6%)	14 (6.6%)
How well managing financially	***			
Difficult	701 (11.2%)	495 (7.2%)	34 (12.0%)	28 (13.1%)
Just about getting by	1,987 (31.6%)	1,457 (21.1%)	81 (29.1%)	53 (24.5%)
Doing alright	2,433 (38.7%)	2,561 (37.1%)	117 (41.8%)	85 (39.7%)
Living comfortably	1,165 (18.5%)	2,390 (34.6%)	47 (17.0%)	49 (22.8%)
Means tested benefits received	***			
No	3,797 (61.6%)	5,976 (88.8%)	202 (75.1%)	154 (76.2%)
Yes	2,363 (38.4%)	754 (11.2%)	67 (24.9%)	48 (23.8%)
Country specific IMD decile				
1 - Least deprived	341 (5.4%)	1,119 (16.2%)	2 (0.7%)	8 (3.6%)
2	439 (6.9%)	856 (12.4%)	8 (2.7%)	12 (5.4%)
3	413 (6.5%)	885 (12.8%)	5 (1.6%)	12 (5.5%)
4	466 (7.4%)	756 (10.9%)	3 (1.2%)	3 (1.6%)
5	569 (9.0%)	794 (11.5%)	7 (2.4%)	7 (3.2%)
6	677 (10.7%)	718 (10.4%)	15 (5.5%)	15 (7.0%)
7	623 (9.9%)	582 (8.4%)	15 (5.3%)	15 (7.0%)
8	878 (13.9%)	529 (7.6%)	22 (7.9%)	17 (8.0%)
9	856 (13.5%)	397 (5.7%)	66 (23.6%)	44 (20.3%)
10 - Most deprived	1,057 (16.7%)	287 (4.1%)	137 (49.1%)	83 (38.3%)
Subjective environmental harshness score [b]	0.18 (±0.03)***	-0.30 (±0.02)	0.25 (±0.12)	0.16 (±0.10)
n	*5,841*	*6,540*	*261*	*191*
Objective environmental harshness score [b]	0.10 (±0.03)***	-0.48 (±0.02)	0.53 (±0.13)*	0.37 (±0.12)
n	*6,108*	*6,725*	*270*	*211*
Parental death	**			
Both parents still alive	4,574 (83.5%)	5,026 (80.5%)	184 (74.9%)	127 (70.1%)
Mother alive only	578 (10.6%)	810 (13.0%)	40 (16.5%)	39 (21.5%)
Father alive only	211 (3.9%)	256 (4.1%)	16 (6.6%)	10 (5.3%)
Both dead	116 (2.1%)	151 (2.4%)	5 (2.0%)	5 (3.0%)
Lived away from home before age 17	***			
No	4,884 (81.4%)	5,853 (87.6%)	244 (91.6%)	179 (90.7%)
Yes	1,115 (18.6%)	828 (12.4%)	22 (8.4%)	18 (9.3%)
Parents divorced/separated when a child	***			
No	4,114 (66.6%)	5,467 (80.2%)	265 (96.5%)	200 (95.5%)
Yes	2,066 (33.4%)	1,346 (19.8%)	10 (3.5%)	10 (4.6%)

*Distribution of socioeconomic and environmental characteristics for the two Millennium Cohort Study samples. [a] 0=mean socioeconomic position, positive scores represent greater disadvantage than average, and negative scores represent less disadvantage than average. [b] 0=mean environmental quality, positive scores represent greater harshness than average and negative scores represent less harshness than average. IMD=Index of Multiple Deprivation. Means, standard deviations and ns shown for continuous variables and ns and percentages shown for categorical variables. P-values refer to the differences between classes within each sample; those not attached to any numbers reflect overall p-value for categorical variable below (†p ‹0.10;*p ‹0.05; **p ‹0.01; ***p ‹0.001).*

Table 4.6 Socioeconomic and environmental characteristics by ethnicity and life history class (BiB)

	White British mothers		Pakistani-origin mothers	
	Fast	Slow	Fast	Slow
Socioeconomic disadvantage score [a]	0.41 (±1.06)***	-0.60 (±1.01)	0.06 (±1.02)***	0.28 (±1.05)
n	*2,159*	*1,779*	*2,674*	*1,678*
Education	***		*	
<5 GCSE equivalent	618 (31.6%)	167 (10.5%)	652 (25.5%)	469 (29.6%)
5 GCSE equivalent	885 (45.2%)	470 (29.5%)	845 (33.0%)	511 (32.3%)
A-level equivalent	318 (16.2%)	347 (21.8%)	353 (13.8%)	188 (11.9%)
Higher than A-level	137 (7.0%)	608 (38.2%)	708 (27.7%)	416 (26.3%)
Partner's job status	***		†	
Employed-Non-Manual	766 (39.6%)	1,099 (63.2%)	819 (32.1%)	464 (28.9%)
Employed-Manual	666 (34.4%)	365 (21.0%)	1,035 (40.6%)	668 (41.5%)
Self-employed	173 (8.9%)	201 (11.6%)	480 (18.8%)	344 (21.4%)
Student	42 (2.2%)	11 (0.6%)	37 (1.5%)	16 (1.0%)
Unemployed	290 (15.0%)	63 (3.6%)	179 (7.0%)	116 (7.2%)
How well managing financially	***		*	
Difficult	201 (9.3%)	67 (3.8%)	204 (7.7%)	140 (8.4%)
Just about getting by	674 (31.3%)	338 (19.1%)	584 (22.0%)	429 (25.8%)
Doing alright	845 (39.3%)	740 (41.8%)	1,136 (42.7%)	668 (40.1%)
Living comfortably	433 (20.1%)	625 (35.3%)	735 (27.6%)	427 (25.7%)
Means tested benefits received	***		***	
No	1,074 (49.9%)	1,407 (79.5%)	1,580 (59.3%)	783 (46.8%)
Yes	1,079 (50.1%)	363 (20.5%)	1,084 (40.7%)	891 (53.2%)
Food security	†			
Food secure	144 (67.0%)	159 (74.3%)	277 (86.8%)	203 (87.1%)
Food insecure	71 (33.0%)	55 (25.7%)	42 (13.2%)	30 (12.9%)
IMD quintiles within Bradford	***			
1 - Least deprived	82 (3.9%)	195 (11.4%)	16 (0.6%)	10 (0.6%)
2	337 (15.8%)	508 (29.6%)	146 (5.5%)	105 (6.3%)
3	489 (23.0%)	477 (27.8%)	373 (14.0%)	221 (13.2%)
4	573 (26.9%)	296 (17.2%)	839 (31.5%)	546 (32.7%)
5 - Most deprived	648 (30.4%)	242 (14.1%)	1,292 (48.5%)	788 (47.2%)
DBCM uptake (µg/day)	***		†	
<0.02µg/day	405 (19.2%)	481 (27.7%)	1,093 (41.6%)	746 (45.1%)
0.02-0.03µg/day	687 (32.5%)	529 (30.5%)	922 (35.1%)	554 (33.5%)
0.03-0.61µg/day	1,022 (48.3%)	725 (41.8%)	611 (23.3%)	354 (21.4%)
Nitrogen dioxide (NO_2) (10µg/m³)	2.02 (±0.36)	2.01 (±0.35)	2.23 (±0.38)	2.22 (±0.39)
n	*2,124*	*1,715*	*2,656*	*1,663*
Passive cigarette smoke	***		*	
Unexposed	938 (43.6%)	1,278 (72.2%)	1,970 (74.2%)	1,290 (77.5%)
Exposed	1,215 (56.4%)	492 (27.8%)	684 (25.8%)	374 (22.5%)
Damp and/or mould in home				
No damp or mould	312 (77.8%)	447 (80.3%)	632 (79.7%)	542 (80.3%)
Damp and/or mould	89 (22.2%)	110 (19.8%)	161 (20.3%)	133 (19.7%)
Home centrally heated	*			
Central heating	298 (93.1%)	447 (96.5%)	466 (93.4%)	483 (95.5%)
No central heating	22 (6.9%)	16 (3.5%)	33 (6.6%)	23 (4.6%)

Distribution of socioeconomic and environmental characteristics for the two Born in Bradford samples. [a] 0=mean socioeconomic position, positive scores represent greater disadvantage than average, and negative scores represent less disadvantage than average. IMD=Index of Multiple Deprivation. DBCM=Dibromochloromethane. NO_2=Nitrogen dioxide. Means, standard deviations and ns shown for continuous variables and ns and percentages shown for *categorical variables. P-values refer to the differences between classes within each sample; those not attached to any numbers reflect overall p-value for categorical variable below (†p ‹0.10; *p ‹0.05; **p ‹0.01; ***p ‹0.001).*

direction, in unadjusted and adjusted models, respectively. Parental death amongst MCS White UK-born mothers (mother alive, father dead vs both alive OR: 0.78) and air pollution amongst BiB White British mothers (increase of 10µg/m^3 OR: 0.60) showed the largest significant effects in the *opposite* direction.

Table 4.7: Regressing life history strategy on socioeconomic and environmental characteristics (MCS)

	White UK-born mothers				Pakistani-origin mothers			
	Unadjusted[a]		Adjusted[b]		Unadjusted[a]		Adjusted[b]	
	n[c]	OR (95% CI)	n[c]	OR (95% CI)	n[c]	OR (95% CI)	n[c]	OR (95% CI)
Adult socioeconomic disadvantage								
Socioeconomic disadvantage score	13,246	3.43 (3.22-3.66)***	11,115	2.86 (2.63-3.11)***	496	1.44 (1.14-1.83)**	401	1.31 (0.95-1.80)†
Area-level deprivation (IMD) decile	13,241	***		***	496	***		*
2 vs least deprived		1.68 (1.32-2.15)***		1.45 (1.13-1.86)**		2.75 (0.14-52.88)		2.89 (0.09-88.10)
3 vs least deprived		1.53 (1.17-2.01)**		1.23 (0.96-1.57)		1.62 (0.18-14.71)		2.39 (0.20-28.94)
4 vs least deprived		2.02 (1.54-2.66)***		1.36 (1.03-1.80)*		4.25 (0.74-24.21)		8.84 (0.75-104.67)†
5 vs least deprived		2.36 (1.81-3.07)***		1.40 (1.10-1.79)**		4.04 (0.58-28.20)		2.64 (0.33-20.83)
6 vs least deprived		3.10 (2.38-4.03)***		1.41 (1.09-1.84)**		4.26 (0.49-37.23)		4.62 (0.40-52.88)
7 vs least deprived		3.52 (2.77-4.47)***		1.45 (1.14-1.85)**		4.12 (0.48-35.55)		4.64 (0.50-43.46)
8 vs least deprived		5.46 (4.30-6.92)***		1.80 (1.43-2.26)***		5.45 (0.85-34.74)†		7.38 (1.05-52.11)*
9 vs least deprived		7.09 (5.42-9.27)***		1.95 (1.49-2.56)***		6.35 (1.10-36.73)*		6.13 (1.01-37.38)*
Most deprived vs least deprived		12.12 (9.48-15.50)***		2.12 (1.58-2.84)***		7.01 (1.22-40.34)*		6.84 (1.09-42.95)*
Adult environmental harshness								
Subjective local environmental harshness score	12,381	1.71 (1.61-1.81)***		0.99 (0.92-1.06)	452	1.09 (0.93-1.29)		0.94 (0.76-1.15)
Objective local environmental harshness score	12,834	2.39 (2.21-2.59)***		1.24 (1.14-1.35)***	481	1.22 (1.03-1.44)*		0.89 (0.73-1.09)
Parental death	11,722	**		*	426			
Mother alive, father dead vs both alive		0.78 (0.68-0.90)***		0.80 (0.68-0.94)**		0.72 (0.46-1.13)		0.75 (0.50-1.14)
Father alive, mother dead vs both alive		0.91 (0.71-1.15)		0.89 (0.68-1.16)		1.15 (0.56-2.36)		1.35 (0.64-2.86)
Both dead vs both alive		0.84 (0.65-1.10)		0.78 (0.58-1.04)†		0.62 (0.16-2.42)		0.57 (0.10-3.15)
Childhood environmental harshness								
Lived away from home before age 17 vs did not live away from home before age 17	12,680	1.61 (1.40-1.87)***		0.80 (0.69-0.93)**	464	0.89 (0.50-1.57)		0.94 (0.44-2.01)
Parents divorced/separated when a child vs parents did not divorce/separate when a child	12,993	2.04 (1.84-2.26)***		1.25 (1.11-1.40)***	484	0.76 (0.31-1.85)		1.23 (0.42-3.61)

Associations with probability of adopting a "fast" life history strategy based on the two class models ("slow" class is the reference group). Millennium Cohort Study samples only. [a] Only one socioeconomic *disadvantage/environmental harshness indicator included in each model, each line represents a separate model. [b] Adjusted for other socioeconomic disadvantage and environmental harshness indicators, all rows represent results from the same model. [c] All ns are weighted ns, taking into account the complex survey design of the MCS. OR=odds ratio, 95% CI=95% confidence interval. †p ‹0.10; *p ‹0.05; **p ‹0.01; ***p ‹0.001; p-values not attached to any numbers reflect overall p-value for categorical variable below.*

Table 4.8: Regressing life history strategy on socioeconomic and environmental characteristics (BiB)

	White British mothers				Pakistani-origin mothers			
	Unadjusted[a]		Adjusted[b]		Unadjusted[a]		Adjusted[b]	
	n	OR (95% CI)	n	OR (95% CI)	n	OR (95% CI)	n	OR (95% CI)
Adult socioeconomic disadvantage								
Socioeconomic disadvantage score	3,937	2.48 (2.24-2.74)***	737	1.80 (1.55-2.10)***	4,351	0.82 (0.77-0.87)***	988	1.05 (0.95-1.16)
Area-level deprivation (IMD) quintile	3,847	***		***	4,336	†		†
2 vs least deprived		1.58 (1.17-2.12)**		0.61 (0.22-1.69)		0.87 (0.51-1.47)		1.26 (0.44-3.63)
3 vs least deprived		2.44 (1.89-3.15)***		0.84 (0.30-2.30)		1.05 (0.62-1.78)		1.61 (0.62-4.22)
4 vs least deprived		4.60 (3.51-6.04)***		1.32 (0.49-3.53)		0.96 (0.59-1.56)		1.57 (0.55-4.46)
Most deprived vs least deprived		6.37 (5.02-8.08)***		1.31 (0.53-3.23)		1.02 (0.64-1.65)		2.01 (0.70-5.74)
Adult environmental harshness								
Water chlorination – DBCM uptake	3,849	***		†	4,280	*		*
0.02-0.03µg/day vs <0.02µg/day		1.54 (1.35-1.77)***		1.48 (1.02-2.15)*		1.14 (0.91-1.41)		1.31 (0.94-1.82)
0.03-0.61µg/day vs <0.02µg/day		1.67 (1.42-1.98)***		1.19 (0.88-1.62)		1.18 (1.03-1.34)*		1.40 (1.07-1.83)*
Air pollution - NO_2 (10µg/m³)	3,839	1.10 (0.80-1.53)		0.60 (0.41-0.89)**	4,318	1.08 (0.95-1.22)		0.91 (0.68-1.23)
Exposed to passive smoke vs unexposed	3,922	3.36 (2.80-4.03)***		1.45 (1.03-2.06)*	4,317	1.20 (1.04-1.38)*		1.19 (0.82-1.73)
Damp/mould in home vs no damp/mould	958	1.16 (0.80-1.69)		0.98 (0.64-1.51)	1,468	1.04 (0.77-1.40)		1.10 (0.80-1.51)
No central heating vs central heating	783	2.06 (1.16-3.66)*		2.00 (1.04-3.84)*	1,005	1.49 (0.78-2.84)		1.47 (0.83-2.63)

*Associations with probability of adopting a "fast" life history strategy based on the two class models ("slow" class is the reference group). Born in Bradford samples only. [a] Only one socioeconomic disadvantage/environmental harshness indicator included in each model, each line represents a separate model. [b] Adjusted for other socioeconomic disadvantage and environmental harshness indicators, all rows represent results from the same model. DBCM=Dibromochloromethane. NO_2=Nitrogen dioxide. OR=odds ratio, 95% CI=95% confidence interval. †p ‹0.10; *p ‹0.05; **p ‹0.01; ***p ‹0.001.*

4.8 DISCUSSION

4.8.2 Summary of key findings

We split the four groups of mothers into two classes based on their values for traits in three different behavioural domains (parenting, reproduction and health) to test whether clear “fast” and “slow” strategies could be identified i.e. that these different elements of behaviour clustered together to form distinct response profiles, profiles which were socioeconomically and environmentally contingent. In this way we tested the implicit, and sometimes explicit, assumption that life history strategies are dichotomous, mutually-exclusive and fixed over time. We found that mothers could be split into fast and slow strategists to some extent, but the four groups varied in their probabilities of having fast or slow strategies and how fast or slow they were on particular traits. We found limited clustering of traits both *within* and *between* domains. We found just quantitative differences in traits when mothers were split into two strategies but qualitative differences emerged when we split women into three strategies; defining traits varied by level in the two class models, but by type in the three class models. White UK-born mothers showed more pronounced strategies than the Pakistani-origin mothers, having more significant differences in traits between fast and slow classes. Although life history strategy was predicted by several socioeconomic and environmental characteristics, this was mostly amongst White UK-born mothers and not all relationships were in the predicted direction.

4.8.3 Clustering within and between trait domains

In none of our four groups of mothers did all indicators pattern in the same direction to be faster in one class than another. Our findings therefore suggest that whilst some behaviours pattern together in directions predicted by life history theory, it may be too simplistic to assume that women with one “fast” trait are going to be “fast” on another. A recent study in *Demography* illustrates this point nicely; US mothers who had longer breastfeeding durations had *more* children than those who didn’t breastfeed or who breastfed for shorter durations, and their interbirth intervals were also shorter (Maralani & Stabler, 2018). This suggests that widespread contraceptive use may be decoupling breastfeeding from interbirth intervals. Pakistani-origin mothers in our study showed the same unexpected association between breastfeeding duration and parity (although only significantly so in BiB), but White UK-born mothers patterned as we would expect according to life history theory and economic models of quantity/quality trade-offs in parental investment (Becker & Tomes, 1976), with the fast class having not only lower probabilities of initiating and maintaining breastfeeding, but also higher probabilities of having 4 or more children.

Whilst breastfeeding emerged as an important indicator of life history strategy, other parenting indicators showed little difference between strategies across the groups, suggesting that activities, affection, reading, vaccinating and in utero growth may not be particularly helpful in assigning women strategies. Some of these measures are problematic, not least due to missing values, small cell counts, and loss of information through combining variables, but also for moral reasons. Some of the parenting indicators are based on Western, middle-class assumptions about what mothers should do for their children based on attachment theory. Anthropologists have started to question the universality of attachment theory and have highlighted that child socioemotional development and related parenting practices are culture-specific (Keller, 2018). As such there are both practical and ethical reasons for not relying on ethnocentric metrics of parental investment for classifying parenting strategies.

Whilst our supplementary analysis showed that including health indicators improved class separation, the response estimates in the main analysis showed that they did not pattern cohesively with one another or with traits in other domains. Therefore, whilst health indicators helped to discriminate between groups of women effectively, they may not reflect the same underlying concept of life history strategy in our samples. The higher chances of alcohol consumption amongst “slow” mothers may be driven by women of higher socioeconomic position drinking more, since this is one of the few ‘unhealthy’ behaviours which tends to be more common in advantaged groups. However this socioeconomic differential in alcohol consumption was not sufficient to change the direction of association between socioeconomic disadvantage and life history strategy. The divergent health indicator patterns could alternatively indicate inadequate indexing of somatic investment. For example, It may have been better to capture amount, duration and frequency of drinking and smoking rather than just using binary indicators (as in Mell et al., 2018). There was also limited variation in the drinking and smoking variables; Pakistani women barely drank at all and had very low levels of smoking, but 63-96% of White mothers drank alcohol and 21-69% smoked. Drinking alcohol and smoking are not fixed biometric outcomes, but behaviours that people may or may not adopt at different times in their lives. Likewise, the mental health and general health indicators refer to a particular point in time and may not accurately reflect health at other points in the life course. In addition, greater bodyweights may have corresponded to higher BMIs in some cases, which may arguably capture *reduced* rather than increased investment in own health.

4.8.4 Ethnic differences

We found less pronounced strategies amongst Pakistani-origin mothers than amongst White UK-born mothers. This was not a sample size issue as even though the MCS Pakistani-origin group was much smaller than the MCS White UK-born group, BiB Pakistani mothers were actually more numerous than BiB White British mothers. Perhaps strategies were less pronounced in the Pakistani groups because they may be more heterogeneous. For example, some Pakistani-origin mothers were born in the UK whilst others would have migrated from Pakistan as adults or children. This means that their environmental experiences are likely to have varied more than within the White UK-born groups. Our measures of environmental harshness and socioeconomic disadvantage do not adequately capture earlier life exposure and it may be that Pakistani life history strategies would be better predicted by earlier exposure in Pakistan than by contemporary exposure in the UK. Acculturation is likely to play a key role. Previous analyses using the MCS have shown that whilst babies of South Asian descent had similar odds of being breastfed to White babies, immigrant mothers were less likely to initiate breastfeeding the longer they lived in the UK (L.J. Brown & Sear, 2017: supplementary material; Hawkins et al., 2008), perhaps reflecting the importance of sociocultural rather than physiologically-based ethnic differences.

Relating our findings back to the weathering hypothesis, we would expect to see the Pakistani mothers exhibiting particularly “fast” behaviours if they were experiencing the persistent stress associated with structural racism. We found that the life history strategies of the Pakistani mothers were however not overwhelmingly faster and so it seems unlikely that social discrimination is resulting in further behavioural modifications in this ethnic group. The experiences of Pakistani-origin mothers in the UK are clearly not the same as that of African Americans in the US, with migration status being the most obvious difference between the two groups. As such, the US Hispanic population may be a better comparator for the UK Pakistani population (since the US Hispanic population contains a higher proportion of recent immigrants than the US black population (Migration Policy Institute, 2018)). Research on weathering or trait clustering in the Hispanic population is however lacking, making direct comparisons difficult. Rare examples of studies that have looked at the US Hispanic population in this light found that foreign-born Hispanic mothers had lower odds of having a low birth weight baby than Hispanic mothers born in the US (Acevedo-Garcia, Soobader, & Berkman, 2005) and foreign-born Mexicans had lower allostatic loads than US-born Mexicans, Non-Hispanic Blacks and Non-Hispanic Whites (Kristen Peek et al., 2010). These examples suggest that immigration status may be a more important determinant of reproductive, parenting and health behaviours than ethnicity per se, and that sociocultural practices play more of a role than the experience of racism for some groups.

Pakistani sociocultural norms and practices may mean that Pakistani groups favour stable unions, a "slow" life history trait, but also the "fast" traits of a relatively early age at first birth (H. S. Kaplan & Lancaster, 2003) and high parity (Coleman & Dubuc, 2010; Kulu & Hannemann, 2016). Our findings that age at first birth and union stability were less variable across life history classes amongst Pakistani-origin mothers than White UK-born mothers and that their chances of high parity were between 1.3 and 6.6 times higher reaffirms that such sociocultural constraints may have played a key role in shaping the Pakistani mothers' behaviours. The less extensive clustering of traits in this ethnic group also implies that certain culturally-enforced traits are relatively resilient to novel environmental conditions.

4.8.5 The importance of socioeconomic disadvantage and environmental harshness

Life history strategy based on the two class models was fairly reliably predicted by various socioeconomic and environmental harshness indicators, lending support to adaptationist perspectives of behaviour. There were however a couple of exceptions. Firstly, BiB Pakistani mothers were more socioeconomically disadvantaged than BiB White mothers but showed less variation (mean 0.14, SD 1.04 vs mean -0.05, SD 1.15) potentially explaining why greater socioeconomic disadvantage in the BiB Pakistani mothers predicted *lower* chances of adopting a fast strategy. Secondly, MCS White UK-born mothers who experienced parental death or lived away from home before age 17 had *lower* chances of adopting a fast strategy.

Our socioeconomic disadvantage measures generally had larger effects on strategy membership than our environmental indicators, with the exception of having no central heating which doubled the odds of adopting a fast strategy in BiB White British mothers. As our socioeconomic disadvantage measure was derived from education, income and job status indicators, we are unable to pinpoint which individual aspects were particularly important for predicting life history strategy. In concordance with our previous breastfeeding-focused research (L.J. Brown & Sear, 2017), the objective measure of local environmental harshness was a more robust predictor of life history strategy than the subjective measure. This is in contrast to research which emphasises the importance of perception or subjective environmental experience in translating environmental quality into behavioural responses (e.g. D. Amir, Jordan, & Bribiescas, 2016; Johns, 2011).

Some life history events such as menarche and age at first birth will predate contemporary socioeconomic/environmental conditions (D. Amir et al., 2016; Ellis, 2004), but others occurring later on in the trajectory, such as parental investment, are plausibly still affected by contemporary environmental exposure (Coall et al., 2016; H. S. Kaplan & Lancaster, 2003) and there may be some elements of life history strategy that respond to new environmental information throughout the lifespan (Kubinski et al., 2017). Early life environmental conditions are nevertheless thought to be particularly important for calibrating life history strategies as harshness in childhood may directly impair somatic state or serve as a cue for later environmental conditions (Rickard et al., 2014). As well as epigenetic effects (Beach et al., 2016; Romens, Mcdonald, Svaren, & Pollak, 2015), our autonomic, neuroendocrine, metabolic and immune systems track environmental information (Cabeza de Baca & Ellis, 2017; Vitzthum, 2009). Physical and social environments can affect our physiology in similar ways, with for example the chemical compounds in air and water and the experience of parental separation both having endocrine disrupting potential (Alvergne, Faurie, & Raymond, 2008; Pedersen et al., 2013; Rosen-Carole et al., 2017; Toppari & Juul, 2010). The consequent "biological stress responses regulate the coordinated development of a broad cluster of life history-relevant traits" (Cabeza de Baca & Ellis, 2017). This coordination may depend on consistent environmental information and using childhood environmental conditions to predict adult environmental conditions may only create optimal strategies if the two environments are similar (Alvergne et al., 2008; Nettle, Coall, & Dickins, 2011). Whilst other studies have shown that women who experienced childhood stress are more likely to experience adult stress (Coall et al., 2016), correlations between our childhood and adulthood environment measures were weak at best (Table C.5). Although they captured different environmental levels (family versus neighbourhood conditions), this could suggest that adverse childhood conditions are not necessarily associated with adverse adult conditions, and therefore a reliance on childhood information may result in behaviour less well-suited to adult condition (i.e. there is a "mismatch"). This may go some way to explain the negative association observed between some of our childhood measures and fast strategy membership. We do not know age at parental death, but if this occurred when the focal mother was a child, this may explain why relationships between parental death and strategy membership patterned similarly to the childhood indicators. We would have liked to have included more childhood environment measures but these were not available in our chosen datasets. Future work would benefit from indexing childhood environment more thoroughly and looking at the interaction between childhood and adult environment in predicting life history strategies.

4.8.6 Limitations and future research

Whilst latent class analysis has been helpful in critiquing the dichotomous application of life history theory by showing the limited extent to which women can be split into two extreme strategies, in doing so we have lost some of the informative variation women show in specific traits. However, this problem occurs in the use of factor analysis too, another data reduction technique used in several other life history studies (Bielby et al., 2007; Mathes, 2018; Milne & Judge, 2012; Olderbak, Gladden, Wolf, & Figueredo, 2014). The variation in probability of class membership in the present study (Figure 4.1) suggests that a fast-slow continuum may be a more informative way of conceptualising women's reproductive, parenting and health behaviour. Perhaps this may have been better indexed with factor analysis rather than latent class analysis as a key difference between the two methods is that the former assigns individuals a continuous score whereas the latter assigns a group.

Our choice of life history indicators was restricted by what was available in our two datasets. Future work could include other indicators such as menopause, age at first sex, relationship trajectories, age at death and number of grandchildren to give a more comprehensive account of life histories. It is also noteworthy that menarche is not the only way to index puberty and captures a relatively advanced level of pubertal development rather than the onset of puberty per se (Ellis, 2004). Using other pubertal indicators may have yielded stronger class differences on this metric. Though menarche is a relatively crude indicator of puberty it has been used successfully in many previous studies in high-income populations to demonstrate associations between early life events (e.g. father absence) and age at puberty (Alvergne et al., 2008; Chisholm et al., 2005; Gaydosh, Belsky, Domingue, Boardman, & Harris, 2018).

An obvious limitation to this work is its sole focus on women. Whilst this may be justified by their greater trade-off between physical growth and production of offspring, and their greater levels of somatic (and extrasomatic?) parental investment (H. S. Kaplan & Lancaster, 2003), men are of course also subject to evolutionary forces and their behaviour will reflect resource access and environmental harshness too. As our samples comprise mothers of cohort children, they are also necessarily restricted to parous women. It is therefore not clear how our findings would translate to nulliparous women. That said, it is also not clear how nulliparous women would fit into a life history framework about clustering of traits since they are not expending any reproductive effort. It may however be useful to investigate trait clustering in young women on the basis that they haven't reproduced yet as they are still investing in somatic effort.

We use cohort data, but only from a few cross-sectional snap-shots of time. This exploratory work would benefit from replication with truly longitudinal data. We focus on their mothers here, but the MCS and BiB cohort children are now growing up and future research looking at their life histories would provide further insight to the extent of trait clustering[2]. The socioeconomic and environmental conditions their parents (the mothers in this study and their partners) experience could be used alongside indicators of their adult conditions to explore how social mobility and altered environmental quality alter behavioural responses. Given the likelihood that individual and environmental circumstances will change over the life course (for some individuals), a longitudinal perspective will reveal whether behaviours related to reproduction, parenting and health really all cluster together to form distinct strategies or, whether behavioural flexibility manifests as a relatively disjointed presentation of traits. Exploring intergenerational transmission of strategies will likely be another fruitful avenue of research. Another suggestion for further research would be to see how indicators and traits pattern in other contexts - in other high-income countries but also in low- and middle-income countries.

4.8.7 Theoretical implications

Our results suggest that there is great variation in women's reproductive strategies and also the extent to which they are environmentally influenced, even within a high-income context like the UK. This highlights the importance of segmenting populations into subgroups when looking at large, complex ad stratified societies.

Our models included the biometric indicators of menarche, age at first birth, parity, child's birthweight and gestational age and breastfeeding, but we also included other less definitive indicators such as the other parental investment indicators and indicators in the health domain. It is interesting that we see clearer class separation in our more physiological markers than our behavioural markers[3], perhaps questioning the extent to which a theory derived from mammalian reproductive events in evolutionary biology

[2] Wave 6 of the MCS (collected when children were aged 14) includes pubertal indicators and these could be used alongside data from future surveys to explore life history strategies in this cohort

[3] We note that classifying traits as physiological vs behavioural is problematic, especially for biocultural practices like breastfeeding (Allen & Pelto, 1985; Fouts, Hewlett, & Lamb, 2012).

can be extrapolated to peculiarly human endeavours such as reading and drinking alcohol.

Age at first birth is a key indicator used to differentiate between different women's trajectories in the diverging destinies (McLanahan, 2004), weathering (Geronimus, 1996; Goisis & Sigle-Rushton, 2014) and life history frameworks (Bobbi S. Low et al., 2008; Uggla & Mace, 2015b). Our results largely support the use of reproductive indicators to index life histories, but interestingly, breastfeeding, an indicator of parental investment, emerged as a particularly important distinguishing feature of strategies in our study. Breastfeeding is often seen as an outcome of a particular strategy, but our study highlights how it can be used as an important indicator too.

The lack of correlation between health indicators and the other traits in our study suggests that we cannot assume a woman's reproductive or parenting behaviour based on her health behaviour, and vice versa. Whilst evolutionary models suggest that these domains are linked through trade-offs between investing in oneself and investing in having children, this doesn't appear to be reflected in our data. Our results suggest that relying solely on health indicators would result in misclassification of other traits. Furthermore, given the lack of cohesive clustering found when biometric and actual behavioural outcomes were used, we advise particular caution when extrapolating life history strategy based on purely psychometric and hypothetical behaviour indicators.

4.8.8 Policy implications and conclusion

Reproductive and parenting behaviours did cluster fairly well together, suggesting that women who are on the fast-track to becoming mothers are also those who may struggle to breastfeed and support their children with other activities. Identifying likely patterns of behaviour may be helpful in health and social care settings, but given the limited clustering between domains, we stress the importance of not assuming too much. Women's behaviours in one domain are not necessarily well-predicted by behaviours in another. This calls for an individualised approach to reproduction, health and parenting support.

The relatively robust links we find between socioeconomic and environmental conditions and life history strategy do however suggest that an individualised approach is not enough. The benefit of an evolutionary stance above other more proximate understandings of behaviour-environment interactions is that it enables us to understand seemingly problematic or risky behaviour instead as adaptations to local context, with women making the most of their socioeconomic and environmental circumstances. Acknowledging the merits of this flexibility does not however mean that we do not have a moral obligation to reduce the socioeconomic inequalities that mothers experience. Whilst women may adapt their behaviour as best they can, improving environmental conditions and redistributing resources more equally will mean that women will have more freedom in their behavioural repertoires and will not be as constrained to pursue a given reproductive, parenting or health destiny. Deciding how best to alleviate these health inequalities is tricky. Whilst our results do not identify one particular avenue for intervention, a general policy push towards environmental and structural interventions is warranted; "bundle" interventions are still helpful even if we do not know the main drivers or mechanisms (Glymour et al., 2014). We must continue to push for the importance of shifting some of the focus away from individuals, and instead towards the socioecological contexts in which they find themselves.

5. DISCUSSION

My thesis adds to existing literature by presenting a thorough examination of the influence of environmental quality on breastfeeding in much more detail than is usually done in life history theory work. Previous studies have tended to use a single measure of environmental quality, often using socioeconomic status as a proxy and/or ignoring how subjective individual experience might moderate effects. My first study investigated environmental quality in both subjective and objective terms, using both sociocultural and physical elements to construct holistic summary measures of local environmental experience, and tested for interactions with socioeconomic status to see if women with more resources were buffered against environmental adversity. In doing so, this first study presented a more nuanced assessment of what “environmental quality” means and how the concept can be meaningfully measured.

My second study departed from summary measures of the environment to focus instead on specific physical aspects of the environment to better understand potential causal mechanisms and avenues for intervention. This study also explored ethnic differences, thereby addressing another element of societal stratification often omitted from life history research, and highlighting another important axis of variation. For example, greater exposure to water chlorination chemicals only impacted the breastfeeding chances of Pakistani-origin mothers, whilst household damp and mould and increased exposure to air pollution increased White British mothers’ chances of initiating and maintaining breastfeeding, respectively. This paper further illustrated that how the environment is measured is important, with different indicators having different associations with breastfeeding. It also showed that socioeconomic status, ethnicity and environmental quality cannot be used as proxies for one another, with each exerting their own effects.

My final paper situated breastfeeding within a broader range of parenting, reproductive and health behaviours to test whether different behavioural traits cluster together to form dichotomous life history strategies, and the extent to which behavioural repertoires varied by ethnicity, SES and environmental conditions. I found that whilst women could be split into “fast” and “slow” strategists to some extent, and breastfeeding was a key indicator driving this split, the overall level of trait clustering was low, with health behaviours not patterning neatly with reproductive and parenting behaviours, and Pakistani-origin mothers showing less pronounced life history strategies than White UK-born mothers. Overall, my thesis has shown that mothers' infant feeding (and other reproductive and parenting) behaviour is affected by environmental conditions, but that certain aspects of the environment have stronger influences, and certain groups are more vulnerable to environmental insults. I now turn to discuss each of my key findings in more detail before moving on to focus on policy implications in the next section.

5.1 THEORETICAL CONTRIBUTIONS

5.1.1 Life history theory as an explanatory framework of reproductive behaviour in the UK

Both ecological and political economic perspectives are important for understanding human reproductive, parenting and health behaviour. Life history theory serves as a unifying framework, one that considers the broader evolutionary context in which infant feeding "decisions" are made but also bridges the public health literature as well as social anthropology and sociology, with its consideration of the social determinants of health, political economy and social stratification.

The social determinants of health framework acknowledges that health inequities arise from the conditions in which people are born, grow, live, work and age and that these key components of health (in)equity are in turn influenced by structural drivers such as societal values, economics, power distribution, gender equity and policy frameworks (Michael Marmot, Allen, Bell, Bloomer, & Goldblatt, 2012). The social determinants of health model acknowledges the complex interrelations between natural, built, and social environments and that power, money and resources affect conditions of daily life (Michael Marmot et al., 2012) and in this way resonates with my conceptualisation of the importance of environmental quality, socioeconomic status and ethnicity in determining infant feeding decisions. However, even with thorough consideration of individual and structural drivers at both proximate and increasingly more distal levels, the social determinants of health framework lacks an ultimate level of explanation; this is where the nuance of life history theory comes in. By further contextualising reproduction, parenting, and health within an evolutionary perspective, we are able to understand *why* women behave the way they do. That is, by framing behaviour in terms of reproductive success (i.e. propagating genes to the next generation) we can understand behaviour as context-specific responses with ultimate objectives. This means that the social determinants framework can sit within the life history framework, as they are not at odds with one another, but offer instead complimentary stances.

A WHO review of the social determinants of health in Europe recommended that adequate social and health protection needs to be provided for pregnant women and mothers, including services to increase breastfeeding, emphasising that such services should ensure at-risk families are identified and supported early on (Michael Marmot et al., 2012). In terms of ethnicity-related recommendations, this review calls for the inclusion of ethnic minority groups in early years childcare and education but doesn't address how adult experiences may be ethnically patterned or explicitly discuss how ethnicity interacts with other social determinants to predict health outcomes. By integrating ethnicity into life history approaches to behavioural variation in the UK, my research therefore improves upon this social determinants approach.

5.1.2 Operationalising socioeconomic status

As discussed in the introduction to this thesis, socioeconomic status is a multifaceted construct and can be measured in various ways. It cannot be wholly captured by any one indicator, as its separate components are likely to have overlapping but distinct influences on many health and behaviour outcomes. This was shown for maternal and infant health outcomes in a thorough exploration of how indexing socioeconomic status impacts associations differently depending on ethnic/racial group studied in a Californian sample (Braveman, Cubbin, Marchi, Egerter, & Chavez, 2001). This suggests that my approach of collapsing various SES components into one latent variable in Papers 2 and 3 was appropriate, even though its drawback is that it precludes examination of component-specific effects. I did look at different indicators of SES separately (as well as all together in the same model) in Paper 1, which addressed a recommendation made in the Braveman paper – that it is important to check that conclusions are not sensitive to the choice of SES indicators used. As reported in Paper 1, the effects of the subjective and objective environmental quality measures did not differ substantially according to which indicators of SES were controlled for. As is to be expected, the models which included income, education and job status indicators simultaneously showed the most attenuated effects because more of the residual variance was explained. Models that control for different SES indicators simultaneously can highlight which indicators have particularly strong influences on the outcome of interest. Looking at the models exploring the effect of objective environmental quality on breastfeeding initiation and duration in Paper 1 as an example (Table A.7 in Appendix A), we can see that education appeared to be a particularly important driver of breastfeeding outcomes, showing larger effect sizes and lower p-values than job status and occupation when all these indicators were controlled for. This means that for mothers with similar incomes and similar jobs, education plays a defining role in infant feeding, with those with no qualifications having the lowest chances of initiating and the highest chances of stopping. There was a dose-response effect whereby the more qualifications a mother and/or her partner had, the greater the chances of starting and maintaining breastfeeding: mothers with Levels 3 to 5 qualifications were more than twice as likely to initiate and 35% less likely to stop breastfeeding compared to those with no qualifications, and mothers with Level 6 or higher were more than four times as likely to initiate and 43% less likely to stop. The relatively more important role of education over occupation and income has been reported in a Californian sample as well (Heck et al., 2006) and suggests that tackling inequalities in education may be particularly fruitful for improving breastfeeding rates.

Across the three papers I have used a relatively comprehensive set of SES indicators, and particularly so in Papers 2 and 3, where in addition to income, education and job status, the latent SES measure was further based on whether the family were receiving means tested benefits, how well they were managing financially and food insecurity. My operationalisation of SES has improved upon traditional indicator usage, exploring differential effects and capturing a more holistic version of socioeconomic position. That said, even with these different operationalisations, I have not completely captured wealth and have been unable to fully account for power relations and network effects (although the job status component gets at this to some extent). Housing tenure may be another good indicator to use in future analyses, although it is not without its own limitations (i.e. it may not reflect wealth very well, like in the case of a student renting for example, and may be more indicative of housing market prices than individual circumstances). Whilst likely contributing factors to breastfeeding differentials, such components of SES were not the main focus of my thesis. The more significant contribution of my thesis lies in my thorough examination of environmental quality, and in setting its influence apart from that of SES, as I discuss in more detail below.

5.1.3 Operationalising environmental quality

This thesis has both constructed and deconstructed environmental quality in several ways, and in doing so has provided a thorough examination of environmental influences on women's infant feeding behaviour. The environment is key to much life history work, as the environment influences life history decision-making. But there are many aspects of "environmental quality" which could influence such decisions[4]. For example, environmental quality could be an indicator of resource access; it is also sometimes assumed to be an indicator of mortality risk. "Environmental harshness" is a term bandied about the life history literature and it is often not clearly defined or broken down into its constituent parts. Where it has been operationalised, it is usually delineated into "extrinsic mortality risk" or sometimes "environmental uncertainty" or "environmental unpredictability".

The use of evolutionary theory in high income countries has been questioned given that individuals no longer act in a way that optimises their reproductive success (Goodman, Koupil, & Lawson, 2012). The life history framework nevertheless suggests that humans have evolved to recognise environmental cues to calibrate their reproductive and parenting behaviour (Stulp, Sear, & Barrett, 2016). In a high-income context like the UK, where environments pose less direct risks to mortality, arguably it is better to not just rely on mortality cues but to also focus on morbidity cues. Environmental circumstances do fluctuate, but are less stochastic than in our evolutionary past, perhaps rendering explorations of uncertainty and unpredictability less fruitful in this context. My thesis has drilled down to focus on women's actual environmental experiences, rather than those proxied by aggregate measures like the index of multiple deprivation (IMD). By using indicators that are individualised, such as women's own opinions of their

[4] Decisions do not necessarily involve conscious decision-making

neighbourhood and water chlorination chemical exposure calculated according to personal activity and consumption patterns, my work provides more reliable estimates of the link between environment and behaviour. However, what constitutes a "harsh environment" is still up for debate. Not all the environmental harshness indicators used in my research predicted breastfeeding initiation and duration, highlighting the nuance of this concept.

Within the framework of life history theory, the environment is conceptualised broadly and environmental harshness refers to extrinsic morbidity and mortality risk, i.e. any external influence that potentially endangers health and longevity. This is a broad remit and such threats are however variably and vaguely defined in the life history literature; one of the driving impetuses for my PhD was to improve upon this by breaking down the environment into different measurable components, to explore how environmental quality could be captured and operationalised in the UK. This exploration necessarily involved using different environmental measures throughout the thesis. In part, this was to try and determine which particular aspects are influencing behaviour, and to inform policy recommendations. I could have gone down the sociocultural route more, but this is relatively well explored – in terms of the influence of SES, norms, cultural influences, religion etc. on breastfeeding at least, and therefore my focus shifted towards the more physical components of environmental quality. Physical components, such as pollution, have the added importance of being aspects that are amenable to change, unlike aspects of the sociocultural environment which are more difficult (or even inappropriate) to intervene upon. Whilst I acknowledge the broader-level drivers such as infant feeding policy, the marketing of breast milk substitutes, cultural norms etc., the environmental focus in my thesis was narrower, focussing instead on local factors at the street and neighbourhood level.

In Paper 1, I compared objective and subjective summary measures of the local environment using factor analysis to pull together both physical aspects (such as levels of litter, graffiti and building conditions) as well as sociocultural aspects (such as safety, experience of racism, and observations of people arguing or fighting on the street), whilst in Paper 2 I focused instead on specific aspects of the physical environment (water disinfectant by-products, air pollution, passive cigarette smoke, and household condition). Paper 3 used both of these sets of environmental measures alongside a couple of indicators of adverse childhood experience - parental separation and living away from home before age 17 in the MCS (and parental death to some extent, assuming this variable indexed death in childhood). I think the contrast between operationalising and conceptualising the environment is an important one, as the former was more the focus of my PhD than the latter. My conceptualisation of the environment was such that it expanded upon the use of vague terms in the life history literature and focused on individualised measures rather than aggregate level data. The different datasets had different measures of environmental quality available and therefore lent themselves to explore different aspects. My shift from a focus on mothers' individual environmental perception (i.e. subjective versus objective environmental quality) in Paper 1 to the more subtle physical aspects of the environment in Paper 2 in no way negates the role of other broader or more sociocultural aspects of the environment, but just reflects my shift in thinking and the exploitation of a clear research gap in the literature.

Figure 5.1: Conceptual framework

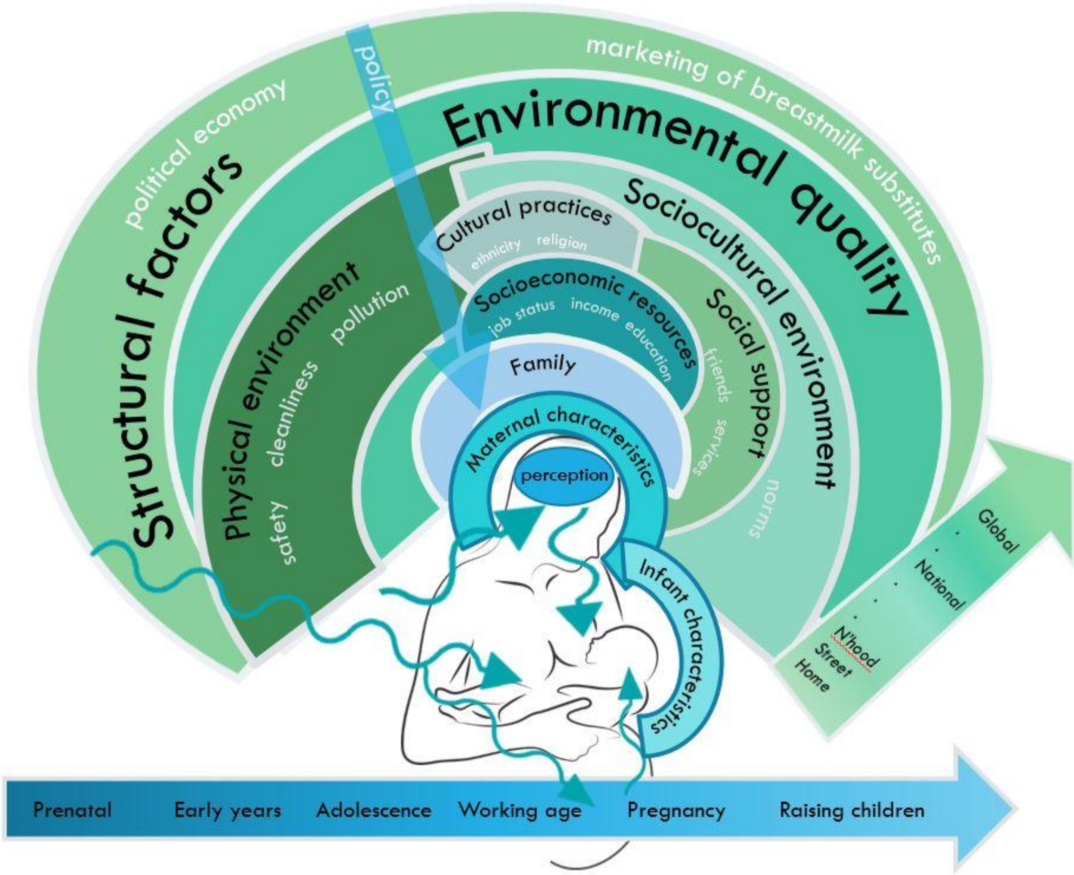


Figure 5.1 shows my conceptualisation of environmental effects on breastfeeding that has developed throughout my PhD. This diagram shows that human environments are complex, multi-layered and with many intersecting influences. They also change throughout the life-course and can influence maternal behaviour physiologically and psychologically, directly and indirectly. The layers of environmental influence explored in this PhD, namely environmental quality and its constituent components of the physical and sociocultural environment, are nestled within broader structural factors. Policy has the potential to intervene at multiple layers.

I now turn to contrasting various combinations of the main measures used in my thesis to try and ascertain which measure(s) best capture environmental harshness. These delineations are, however, somewhat arbitrary and as such there is some cross-over discussion in the sections that follow.

5.1.3.1 Multiplicity versus specificity

What are the ideal metrics of environmental quality? How is it best measured? This will depend on the research question of interest, but mothers, and others, are exposed to a whole array of environmental conditions at once. We are processing information about our surroundings all the time. How best to capture this reality empirically is, however, challenging. I attempted to do this in Paper 1 but it was not possible to create a single summary measure of environmental experience as different aspects were indexing different axes of influence. I anticipated physical and sociocultural aspects to separate into two clusters but instead found that divisions were made by who was processing the environmental information rather than the type of environmental information being processed. What's more, four of the sociocultural environment indicators did not load on to either of the two factors, nor did they load together. This suggests that support from friends, other parents, neighbours and health professionals are distinct aspects of the sociocultural environment and cannot be condensed down into one measure. In practice, this means that the support mothers receive from one group of people is not related to the support they receive from other groups. This is a little surprising as we might expect a mother who has no support from her friends to be more likely to turn to support elsewhere (and so a negative association to be apparent between at least some of the different indicators).

Paper 2 reflected a shift in thinking whereby I moved from using summary measures of environmental experience to focus instead on specific aspects to better identify avenues for intervention. Paper 1's summary measures captured the multiplicity of environmental exposure, but Paper 2 could speak more readily to potential explanatory mechanisms. As we do not experience environmental exposures in insolation, Paper 3 also accounted for the effects of multiple exposure by controlling for all environmental harshness indicators simultaneously in models predicting life history strategy. There are pros and cons to these different approaches, and one is not clearly stronger than the other. Statistical models will never be able to capture environmental experience completely, but varying analytical approaches can help to understand relationships more clearly.

5.1.3.2 Subjective versus objective environmental measures

Assuming the subjective measure of environmental quality used first in Study 1 and then in Study 3 indexed environmental perception appropriately, it is surprising that I did not find stronger associations between this measure and breastfeeding outcomes, or life history strategies more generally as other life history work has emphasised the importance of environmental perception (Fouts & Silverman, 2015; Griskevicius, Delton, Roberston, & Tybur, 2011; Johns, 2011; Mathews & Sear, 2008). The fact that this measure was a weaker predictor of breastfeeding than the more objective measure based on neighbourhood assessments in Study 1, motivated me to explore more subtle, less-perceivable aspects of the environment like air pollution in my second study. However, perhaps the assumption that pollutants are less perceivable only holds in low exposure settings like the UK. Due to the context-specific constraints of different country contexts, the environment-behaviour links found in my research context of the UK may not translate to other settings.

It would be interesting to look at the effects of pollution on breastfeeding both directly and indirectly through adverse birth outcomes, as well as its effects on life history strategy in contexts with greater levels of pollutant exposure. Not only will the detrimental physiological impacts likely be greater where exposure levels are higher, but increased exposure is also likely to be more perceivable – both through visual cues, such as visible fumes or smoke, and increased public awareness of the issue (e.g. policy trying to reduce emissions, people wearing face masks etc.). This may, however, mean that untangling consciously-altered behaviour from direct physiological effects may be more difficult, at least if only quantitative data on exposure and outcome levels is used. In other words, without actually asking mothers whether their infant feeding choices have been shaped by environmental exposures i.e. directly addressing the role of perception, we would be left just speculating about whether any links found are deliberate behavioural adjustments. Some of the results of my second study suggest that mothers may actually increase investment through breastfeeding in response to environmental harms (air pollution and household damp and mould) but we cannot say whether this is a conscious response to the environmental situation. Future research would benefit from collecting qualitative data to ascertain whether mothers are actively perceiving exposures and choosing to alter their behaviour, or whether there is instead a sub-conscious response to environmental threats.

5.1.3.3 Physical versus sociocultural aspects of the environment

The proximate links that socioeconomic factors (e.g. education, income, job status) and social support (e.g. breastfeeding cafes, having supportive family members) have on breastfeeding are relatively well understood. My research focused more on the distal influences on infant feeding behaviour in the UK. Where Study 1 looked at local environmental experience generally, capturing perceivable and observable environmental conditions, Study 2 focused largely on more subtle aspects of the environment. This is not to say that physical environmental attributes are always more subtle or less perceivable than sociocultural environmental attributes, but rather that where exposure levels are low, they may provide less salient cues. These cues may not be processed by the mind, even when they are processed by the body.

Social cues may be more likely than physical cues to be consciously processed, perhaps being particularly salient in social species such as ours. Sociocultural aspects of the environment will be important influences on parenting behaviours, with the burden of parenting likely lessened by the assistance of others (Rebecca Sear, 2018). In addition, breastfeeding requires an element of social learning. Primates are unique amongst mammals in that they require social learning in order to be able to successfully breastfeed their young; and this is particularly pertinent for human breastfeeding (Volk, 2009). My research only explored sociocultural factors to a limited extent. It is, however, acknowledged that breastfeeding-specific support at the family (Negin, Coffman, Vizintin, & Raynes-Greenow, 2016; Tohotoa et al., 2009; but see Emott & Mace, 2015), community (Fox et al., 2015; Pérez-Escamilla, Martinez, & Segura-Pérez, 2016), and wider-society (Ashmore, 2016; Sriraman & Kellams, 2016) levels has established links with breastfeeding. My work departs from sociocultural influences by largely operationalising environmental quality with physical aspects of the environment. Both the objective and subjective summary measures created in my first study (and also used in my third study) did include a mix of physical and sociocultural aspects of the environment (as is set out in Table 2.1), but the sociocultural items that loaded onto these measures did not index social learning or support per se, and can be better thought of as capturing safety and community cohesion. Four of the eight items that did not load onto either factor perhaps serve as better indices of social support and learning: (1) whether a mother sought support since birth, (2) how often she spent time with her friends in the last week, (3) whether she has other parents to talk to, and (4) how friendly she thought her neighbours were. Their associations are detailed in Tables A.4-A.7 and in Section A.2.2. None of these social support/learning measures had as large an effect on breastfeeding initiation as did a one unit increase in the objective environmental quality measure, but having other parents to talk to and seeing friends 3-6 times a week did have a larger protective effect on breastfeeding duration. This highlights that there may be different barriers for initiation and duration, a point I come back to in Section 5.1.4.

The two more obvious markers of the physical environment used in Study 2 were those capturing physical aspects of household condition, namely damp and mould and central heating. It is interesting that these more obvious indicators of environmental quality had less robust associations with breastfeeding outcomes, with only damp/mould being a significant predictor once maternal and infant characteristics and socioeconomic position was controlled for, and only for breastfeeding initiation and amongst the White British mothers. Study 1 also included household central heating and damp/condensation as physical environmental quality indicators. Whilst damp/condensation loaded onto the subjective environmental quality measure, central heating access did not load onto either of the summary measures so its effects on breastfeeding are explored separately in Tables A.4-A.7 in Appendix A. Millennium Cohort Study (MCS) mothers were 13-14% less likely to stop breastfeeding when they had no central heating after accounting for maternal and infant characteristics, SES and ward-level factors. Perhaps mothers may consciously compensate for these exposures in ways not captured in the datasets which may protect against any detrimental impact. For example, mothers without central heating are likely to feel the cold and so find other ways to keep warm (e.g. using different heating sources and wearing extra layers). In contrast, low levels of exposure to chemicals in air and water are likely to go unnoticed and represent a more difficult issue to mitigate. It is not clear why we found an effect of central heating on duration in the MCS but no effect of central heating on either breastfeeding outcome in the Born in Bradford (BiB) dataset. There was slightly less variation in the variable in BiB compared to MCS, with around 5% and around 10% of mothers in each sample having no central heating, respectively. Alternatively, differences in temperature in Bradford as opposed to the whole of the UK might contribute to an explanation, with a warmer environment meaning central heating will be needed less.

Sociocultural aspects of the environment are on the other hand more obvious, particularly when they are indexed by mothers' responses to questions about her interactions with others (as with the four indicators that did not load onto either of the two factors in Study 1). In other words, whilst we may passively receive physical environmental information, sociocultural information is usually gleaned through active participation. Social support may be a particularly important influence on life history decisions in a social, cooperatively breeding species such as ours (K. L. Kramer, 2010).

Future work could explore how physical and sociocultural environmental elements interact. I would predict that a supportive sociocultural environment (at various levels e.g. family, friends, work, community etc.) would provide defence against a harsh physical environment to some extent, acting as a buffer similarly to how SES did in my first study. In other words, greater support/less barriers in the sociocultural environment can also be thought of as providing women with additional resources. These additional resources will also impact the trade-offs mothers make in their parental investment decisions. Although interactions were not explicitly tested, Study 3's limited exploration of social support (indexed by parental death) did not support a buffering effect of support on life history strategy as I predicted. In fact, White UK-born mothers who had experienced paternal death were actually *less* likely to exhibit "fast" reproductive, parenting and health behaviours. This is in contrast to the father absence literature which on the whole has shown a relatively robust link between father absence/death and faster pubertal timing in high-income contexts (Webster, Graber, Gesselman, Crosier, & Schember, 2014). Of course, without knowing the focal mother's age at paternal death, it may be that these deaths occurred in adulthood and as such different mechanisms may be operating compared to those that influence reproductive behaviours according to childhood experiences.

5.1.3.4 Adult versus childhood environment

As highlighted in the discussion section of my last study (Section 4.8.5), within life history research childhood is heralded as the key time when future reproductive, parenting and health behaviour is shaped. The importance of early life experiences for forming later health outcomes is also emphasised within life course approaches to epidemiology (Cable, 2014), following on from assertions first made by the Barker hypothesis (Halfon et al., 2014).

My work has, however, shown that adulthood environmental conditions are also important determinants of breastfeeding, as well as life history strategies more generally. The fact that several contemporary environmental exposures were significant predictors of breastfeeding and other life history traits demonstrates that a "critical window" perspective has limited utility for some behavioural domains. In this way, my work has highlighted behavioural flexibility and plasticity: women appear to calibrate behaviour in response to new environmental information, not just potentially out-of-date information from their past. In other words, early experiences do not fully determine later behaviours. My research does not undermine the role of childhood experiences, but rather emphasises that adult experiences are also important.

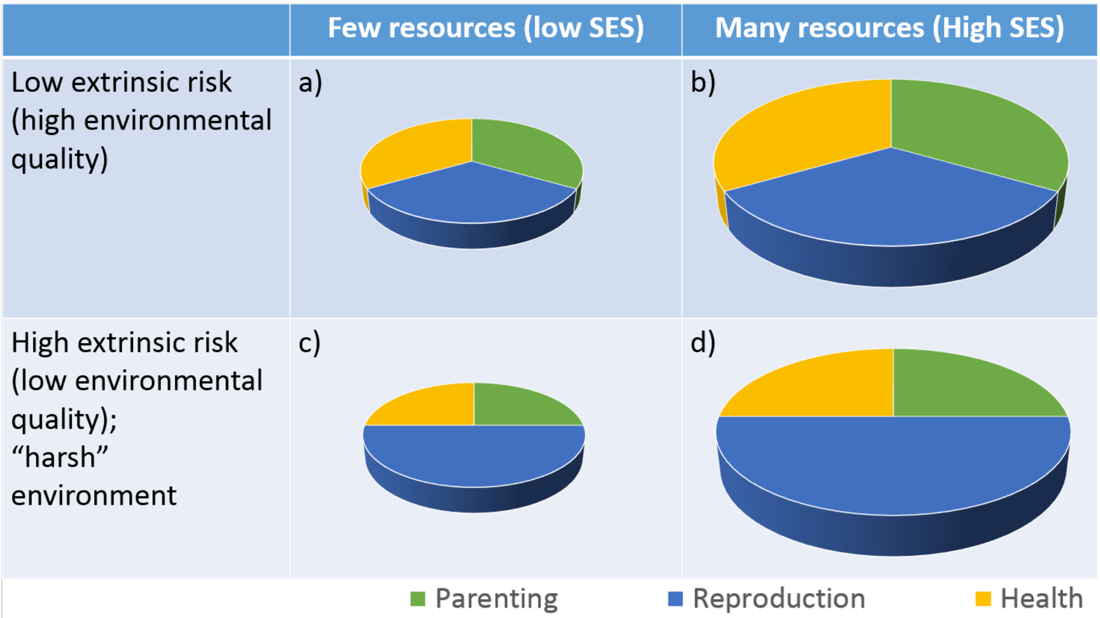
I used almost solely adult environmental harshness indicators in my research, although stratifying my analyses by ethnicity in Studies 2 and 3 may have accounted for differences in childhood environmental conditions to some extent. Depending on if/when they migrated from Pakistan, some of the Pakistani-origin mothers may have spent some of their formative years in Pakistan, potentially experiencing childhood environments quite different from those experienced by mothers born in the UK. However, as the Pakistani groups contain a mix of first- and second-generation immigrants (as well as a handful of women who were born in the UK and whose parents were also born in the UK), there will still be heterogeneous environmental experiences in these groups. In addition, studies that look at childhood environmental harshness usually focus on the psychosocial environment within the home, namely familial relationships (Anderson, 2017; Belsky, 2012; Webster et al., 2014), and the extent to which this varies with immigration is unclear. For example, families could become separated during migration, meaning that the child (the mothers in my studies) could be cared for by just one parent, potentially indicating a harsher childhood environment. Alternatively, both parents may have immigrated together resulting in the child being brought up in a two-parent household (theoretically a less-harsh environment). As well as different immigration experiences resulting in variation in family structure, childhood environmental experiences may also vary according to the level of acculturation. For example, some families may maintain a sense of group identity through the preservation of Pakistani sociocultural norms whilst others may assimilate more into the local community. It's not clear which of the resultant childhood experiences would be less harsh. The point is stratifying by ethnicity only goes a limited way in distinguishing between different childhood experiences. My first study controlled for the effect of ethnicity, immigration and acculturation, my second study stratified by ethnicity and controlled for immigration, and my third study stratified by ethnicity; future work could better explore this variation through further stratification. This would of course require datasets with large enough numbers of women with different combinations of ethnicity, immigration and acculturation to be able to explore this effectively. Such measures would however only proxy childhood environmental experience, and as such we need more specific questions to index this better.

Study 3 included two (possibly three) more specific indicators of childhood environmental harshness: parental separation and living away from home before age 17 in the MCS (and parental death to some extent, assuming this variable indexed death in childhood). Interestingly, amongst White UK-born mothers only parental separation determined life history strategy in the predicted direction once socioeconomic disadvantage and the other environmental harshness indicators had been controlled for; living away from home before age 17 (and parental death) instead conferred *decreased* odds of adopting a "fast" life history strategy. Pakistani-origin mothers showed no associations between the childhood indicators and life history strategy. This contrasts with adult environmental harshness and socioeconomic disadvantage, for which at least some indicators showed significant associations in the predicted directions in both ethnic groups. This suggests that the link between childhood conditions and life history behaviours may be severed to some extent. This has obvious policy implications which I will discuss in Section 5.3.

5.1.3.5 Environmental harshness versus socioeconomic disadvantage

In evolutionary studies, and neighbourhood research more broadly, SES and environmental quality are often conflated, with one used as a proxy for the other. Theoretically, these two measures are thought to capture resource access and extrinsic risk, but are often difficult to disentangle. My thesis findings demonstrate why it is important to separate out these two elements. Figure 5.2 is a simplified schematic illustrating how resource access and extrinsic risk exert different constraints or opportunities for physiological and behavioural responses. Resource access is an important driver of life history decisions, affecting the overall energy budget available, whilst extrinsic risk influences how much budget should be allocated to each domain (S. C. Stearns, 1992). As Figure 5.2 illustrates, if a woman has more resources (i.e. higher income, more education, higher job status), she is able to invest more in absolute terms to each domain than a woman with fewer resources, even though they may choose to invest the same, relatively speaking, in each domain (a versus b in 2). In contrast, in harsh environments, the relative allocation to each domain may shift, with for example more energy allocated to reproduction than health and parenting (a versus c and b versus d). Socioeconomic disadvantage may give women a smaller pie whilst environmental harshness may force her to cut it a certain way.

Figure 5.2: Extrinsic risk versus resource access effects on life histories



Resource access increases the energy budget (size of the pie), whilst extrinsic risk affects how much is invested in different domains (how the pie is cut).

One of the main theoretical contributions of my thesis is that it has clearly shown that individual SES and environmental quality are not the same thing, exerting synergistic but separate effects. SES differentials are not explained away by environmental conditions, and there are some aspects of environmental quality which maintain an influence over breastfeeding (and other life history traits) once individual SES is accounted for. SES does, however, appear to be a stronger determinant of breastfeeding (and other parenting, reproductive and health) behaviours. In all three studies in this thesis, the effects of individual SES on breastfeeding (and life history strategies in Study 3) were generally larger and more robust (i.e. effects existed across different ethnic groups and persisted across different models). I also found stronger evidence for SES associations (i.e. p-values were generally smaller than for environmental quality associations). Taken with the mixed and weak evidence this thesis has found for links between chemical compounds and household condition and infant feeding, this suggests that socioeconomic disadvantage puts stronger constraints on mothers' maternal investment options than physical environmental attributes. The fact that the direction and strength of associations varied according to which aspect of the environment or indicator of SES was used suggests that rather than using general concepts of harshness and resource access as proxy indicators, one should try to disentangle the specific and separate mechanisms at play.

5.1.3.6 Socioeconomic disadvantage versus ethnicity

Whilst ethnicity was not an initial focus of my PhD, it became more important to my research as my project progressed. I controlled for ethnicity, immigration and acculturation in my first paper but did not explicitly focus on their effects on breastfeeding outcomes. My second paper stratified analyses by the two largest ethnic groups in Bradford, to take advantage of this largely bi-ethnic dataset and to build on previous BiB research which has shown variation in both environmental exposure and reproductive outcomes (R. B. Smith et al., 2016). Whilst the MCS over-sampled ethnic minorities (Plewis, 2004), the numbers in different ethnic groups compared to White UK-born mothers was comparatively low. Nevertheless, I decided to stratify my analyses by ethnicity for both datasets in Paper 3. Pakistani-origin mothers comprised the largest ethnic group (after White UK-born mothers) at both the Bradford and national-level. With ethnicity becoming more relevant to my research over time, it warrants further discussion here.

I found that associations were nuanced, with differences in the links between environmental quality emerging by ethnicity as well as SES. This highlights differential susceptibility along different axes. Ethnic differences were not completely accounted for by socioeconomic status as some associations remained after adjusting for SES. This suggests that there is something additionally shaping behaviour that is correlated with ethnicity. There may be residual confounding, resulting from either unmeasured aspects of SES (Braveman et al., 2001) or other factors that pattern according to ethnicity, such as dietary or activity patterns that could be driving the effects seen. Regardless, it is clear that SES and ethnicity cannot be used as proxies for one another. Whilst public health research often finds that SES explains away some of the ethnic/racial disparities in health, the interrelationship between the two is complex. The role of SES on health indicators varies across ethnic groups and is also dependent on which SES indicator is used, with the implication that different aspects of socioeconomic status may be driving effects in different ethnic groups. For example, research looking at a range of SES, maternity and infant health indicators in an ethnically-diverse

Californian population found that education was significantly associated with breastfeeding intention among Latinas, but income was not (Braveman et al., 2001).

Looking at the Table A.3, we see that the Pakistani, Bangladeshi and Indian groups did not significantly differ from White UK-born mothers in the MCS in their chances of breastfeeding initiation or duration in regression models controlling for infant and maternal characteristics, SES and contextual factors. The grouping of ethnicity varies here from that used in my later papers and so the masking effect of heterogeneity cannot be ruled out. In Paper 2, BiB White British mothers had lower levels of initiation than Pakistani-origin mothers (41.66% vs 56.89%) but their durations were similar at around 8 to 9 months (Table 3.1). Considering the initiation and duration patterns across both studies together suggests that, in line with US-based research (Guzzo & Lee, 2008), a large part of the ethnic difference in breastfeeding behaviour is driven by variation in the initial decision to breastfeed. Perhaps more tellingly, immigration status had a dose-response effect on initiation in Paper 1, with all immigrants having higher chances of initiation than UK-born mothers, but immigrant mothers' chances reducing the longer they had been in the UK (Table A.3). For duration, only those who arrived to the UK as adults had significantly lower hazards of stopping breastfeeding. Mothers who spoke language(s) other than English at home also had higher chances of initiating, but not maintaining, breastfeeding than those who only spoke English at home.

Taken together these findings suggest that acculturation may play more of a defining role in shaping women's infant feeding behaviour than ethnicity per se. Acculturation can be thought of as the extent to which people from one culture adapt their behaviour to reflect the norms of another culture. The detrimental influence of UK societal norms on immigrant breastfeeding chances have been reported quantitatively for immigrants generally (Hawkins et al., 2008) and qualitatively for those immigrating from South Asian countries specifically (Choudhry & Wallace, 2012).

Rates of breastfeeding in Pakistan are surprisingly low, with the 2013 Demographic & Health Survey estimating that only 37% of babies under 6 months were exclusively breastfed in the 24 hours before the survey[5] (National Institute of Population Studies, 2013). But rates are still higher than in the UK. The percentage of children who receive any breastmilk at 12 months of age is less than 1% in the UK but more than 70% in Pakistan (National Institute of Population Studies, 2013; Victora et al., 2016). This suggests that mothers transitioning from one society to another are negatively impacted by UK societal norms. This has been shown to be the case for other South Asian immigrant populations in the UK. For example, mothers of Bangladeshi-origin living in London were found to have lower breastfeeding prevalence at 6 months and 15 months than their sedentee counterparts in Bangladesh, and those who arrived to the UK as adults also had higher rates than those who arrived as children (Núñez-de la Mora, 2014). Another study using MCS data found that regardless of ethnicity and controlling for other sociodemographic factors, length of residency had a negative association with breastfeeding duration, with chances of breastfeeding to 4 months reducing by 5% for ever additional five years lived in the UK (initiation was not affected) (Hawkins et al., 2008).

The majority of Pakistani-origin mothers in the UK are likely to hold Islamic religious beliefs (Office for National Statistics, 2013). In Bradford, nearly one quarter of the population identifies as Muslim (City of Bradford Metropolitan District Council, 2018). The Quran and Hadith, the holy book and teachings of the Prophet Mohammed, refer to breastfeeding, providing guidance on its practice. Breastmilk is referred to as "white blood", to highlight its important role in the continuation of nurturing the foetus (Williamson & Sacranie, 2012; Zaidi, 2014). Breastfeeding is considered a deeply spiritual act by Muslim women, one in which the mother's attributes as a "good Muslim" are passed on to her child (Williamson & Sacranie, 2012). South Asian cultural teachings also emphasise the psychological benefits of breastfeeding (Choudhry & Wallace, 2012). The Quran simultaneously promotes sustained breastfeeding by prescribing that "mothers shall give suck to their offspring for 2 whole years" whilst acknowledging that breastfeeding for 2 years is not always possible, and that weaning should be a mutual decision between mother and father (Zaidi, 2014). Whilst on the surface the involvement of the father in the weaning decision may seem a little odd – it is a

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[5] This refers to the diets of infants younger than 6 months during the 24 hours before the survey, not the proportion who are exclusively breastfed for the full 6 month period (Victora et al., 2016).

breastfeeding dyad not a triad after all - babies' fathers play a pivotal role in supporting (or undermining) breastfeeding (Bar-Yam & Darby, 1997). The Muslim father may, however, have a particularly influential role given that the Quran also stipulates that he must provide shelter, food and clothes to the mother and baby for as long as breastfeeding continues (Zaidi, 2014). Relatedly, both Muslim and Pakistani norms promote union stability. This is suggested to some extent by the BiB data, with Table 3.1 in Study 2 showing that fewer Pakistani-origin mothers do not live with their partner (6.9%) compared to White British mothers (28.6%). 2011 Census data suggest that the difference is less stark (and actually in the other direction), with the respective proportions of lone parent households being 8.3% and 6.7%, respectively (GOV.UK, 2018). The Census data also highlight another important cultural difference between Pakistani-origin and White UK-born families of relevance to breastfeeding: the former are far more likely to live in multi-generational households. Having more family members around may mean Pakistani mothers have more social support available than White British mothers. This could manifest as grandparents looking after older children or preparing meals, allowing the mother more time and energy to focus on breastfeeding. But it is also possible that having family members around can be more of a hindrance than assistance. On the other hand, mothers living in multi-generational households may actually favour formula feeding as it allows other family members to feed the baby, freeing them to get on with other household tasks (Twamley, Puthussery, Harding, Baron, & Macfarlane, 2011).

Whilst breastfeeding is promoted in various Quran and Hadith teachings (Zaidi, 2014), the Muslim practices of privacy and covering up coupled with living with extended family or frequent visits from family members (males in particular) can make the reality of breastfeeding at home challenging for Muslim mothers (Choudhry & Wallace, 2012; Yashmin, 2015). Islam's emphasis on modesty may make breastfeeding in public places, such as hospitals, even more difficult for some Muslim women (Zaidi, 2014). However, for hijab-wearing mothers, their clothing, provided it is loose enough (and the baby is happy to be covered) can preserve modesty and help facilitate breastfeeding in public to some extent (Yashmin, 2015). Similarly, the separation of men and women both at home and in mosques may actually help protect breastfeeding (Williamson & Sacranie, 2012). There are however some cultural beliefs and practices which may pose challenges to Pakistani-origin mothers achieving the WHO's breastfeeding recommendations. For example, Pakistani mothers may discard colostrum, believing it to be stale or dirty (Zaidi, 2014), and some even believing that it could kill their baby (Khadduri et al., 2008). Such beliefs have no grounding in religion, but may be reinforced by religious leaders in Pakistan (Zaidi, 2014). The extent to which these cultural beliefs are maintained in the UK is, however, unclear, with small-scale qualitative research suggesting that UK mothers of South Asian origin do not express concern around the giving of colostrum (Twamley et al., 2011).

Immigrant Pakistani mothers may experience two sets of conflict, one between home and host country norms, and another between their religious and cultural belief systems. Such mixed messages may contribute to Pakistani mothers' decisions to formula feed (Choudhry & Wallace, 2012). This is perhaps reflected in the 2005 Infant Feeding Survey which showed that although South Asian mothers had a higher incidence of breastfeeding, they were less likely to be breastfeeding at four weeks compared to White mothers (Bolling C.; Hamlyn A., K.; Grant, 2005). But even with conflicts of identity, Pakistani-origin mothers had higher breastfeeding rates than the White UK-born mothers in both of our datasets (Table A.2 and Table 3.1). Overall then, it seems that sociocultural practices protective of breastfeeding won out over those which threaten it for the mothers in my studies. Ethnicity appears to be another axis by which parental investment is patterned. However, as we have seen in Paper 3, Pakistani mothers' greater chances of breastfeeding does not translate into the presentation of other "slow" life history traits.

As alluded to in the discussion section of Paper 3, sociocultural factors may be exerting constraints on other aspects of reproductive and health behaviour in this group. As well as almost universal marriage, British Pakistani mothers have a high mean ideal family size, low levels of childlessness, and higher progression to third and higher order births (Hampshire, Blell, & Simpson, 2012). Whilst marriage stability indicates "slow" life history, high fertility represents "fast" behaviour. The total fertility rate (TFR)[6] of Pakistani women is around 4.1 in Pakistan but 2.8 in the UK (Coleman & Dubuc, 2010).

[6] TFR is the average number of children that would be born (per woman) among women progressing from age 15 to age 50 subject to the birth rates at each age in the population in question

This is in contrast to White UK-born mothers whose TFR is just 1.7 (Coleman & Dubuc, 2010). But as with breastfeeding, fertility trends amongst British Pakistani mothers hint at a role for acculturation, with for example, first-generation migrants having a TFR of 3.5 but second-generation migrants having a TFR of 2.5 (Coleman & Dubuc, 2010). Although underestimates as they are not reflective of completed fertility, these ethnic differences in fertility are echoed in my datasets, with Pakistani-origin mothers having on average 1.5 other children in addition to the cohort member child, whereas White British mothers only had another 0.9 in Bradford (Table 3.1). Furthermore, at the national level, Pakistani-origin mothers in the MCS have 2.3 to 3.6 times higher chances of having at least four children than White UK-born mothers (Table 4.4). Differing sociocultural norms are undoubtedly important drivers for the ethnic variation in family size observed and relatedly can also drive earlier ages at first birth. We do see some evidence for earlier ages at first birth in the latent class probability estimates in Study 3 (Table 4.4). In the MCS, "fast" Pakistani-origin mothers had their first child on average 2.23 years earlier than "fast" White UK-born mothers (21.37 vs 23.60 years) and the difference between the "slow" groups was 4.32 years (25.43 vs 29.75 years). Differences were not so apparent in the BiB dataset however, with "fast" Pakistani-origin mothers having their first child 3.8 years *later* than "fast" White British mothers (24.82 vs 21.02), although "slow" Pakistani mothers had their first child 3.95 years earlier than "slow" White British mothers (24.93 vs 28.88 years). Interesting work in anthropological demography has shown that whilst family members may hold strong influence on the reproductive couple, the drive for early motherhood and having several children is also shaped by mothers' own desires (Hampshire et al., 2012). In contrast to the assumption of passively receiving sociocultural norms and acting just to please the in-laws, several British Pakistani women interviewed in Hampshire's study in Teeside in Northeast England provided testament to their autonomy and active reproductive decision making. For example, early motherhood facilitated education or employment opportunities later in life for some mothers and desires for having four children reflected fond memories of their own siblings and wanting a complete set (where each child has both a brother and a sister) for others (Hampshire et al., 2012). Quantitative analysis necessitates categorising people somehow to render comparisons feasible. It is clear however that British Pakistani mothers are a diverse group with different influences and decisions. In taking account of immigration status, focus shifts from physiological notions to sociocultural notions of ethnic difference. But a linear view of acculturation is also problematic. We do see dose-response effects on behaviour in quantitative analysis, such as the change in TFR between immigrant generations reported above, but this ignores *how* these changes are brought about. Qualitative research can help to illuminate the proximate mechanisms at play. Second generation immigrants construct their own identities, mixing and matching between cultural influences (Hampshire et al., 2012).

Whilst qualitative research can shed light on how reproductive and parenting behaviours vary in different groups of UK mothers, quantitative research, like the work in this thesis, can highlight broad patterns and universals, potentially illuminating ultimate, rather than proximate, explanations. If environmental quality and socioeconomic status are distinct axes of influence on behaviour, then where does ethnicity fit in? Is ethnicity just a proxy for sociocultural environmental quality, whereby it acts on the trade-offs between different reproductive and parenting decisions, i.e. changing the relative slices of the pie in Figure 5.2, or does it alter the overall size of the pie, akin to the effect of socioeconomic status? The former has been discussed above but the latter explanation requires further consideration of the role of ethnicity-related disadvantage in shaping women's behaviour.

As introduced in Paper 3, the weathering hypothesis posits that the health and reproductive behaviour of ethnic minorities may be shaped by experience of persistent structural racism (Geronimus, 1996, 1997; Geronimus et al., 2006). Predominantly derived from contrasting the health and wellbeing of White and Black Americans, it is not clear how this hypothesis translates to the experiences of the Pakistani-origin mothers in my datasets. Factor analysis based on the England and Wales' Fourth National Survey of Ethnic Minorities conducted in 1993 and 1994 did, however, suggest that at least in the UK context, there are some elements of being an ethnic minority, such as the experience of stigma, that transfer across different groups (Karlsen & Nazroo, 2002). Karlsen and Nazroo's paper also very much emphasised that structural (or "institutional") racism is an issue for minorities in the UK and defined this structural experience in terms of racialisation and social class experience. By this logic, whilst socioeconomic status and ethnicity are related (with minorities often having lower SES than majority groups), the experience of racial discrimination adds another layer of influence on people's lives. Experienced or perceived racism rather than socioeconomic disadvantage per se may be responsible for ethnic/racial inequalities in health (and other) outcomes. Racism can therefore be seen as a marker of environmental harshness, and as such stratifying by ethnicity may effectively be stratifying by environmental experience. This conceptualisation is, however, only borne out by my analyses to a limited extent, and is flawed in the assumption that all ethnic minorities will perceive, experience and respond to racism similarly. Racism can have direct effects on health through the negative physical and psychological repercussions of interpersonal racist experiences, and indirect effects though institutional racism and its exclusionary effects on minorities. Not negating these influences on health and wellbeing, there will still be variation in people's responses. Some people will be more adversely affected, with those tolerating but not reporting racism literally taking it more to heart, as evinced by their higher blood pressure compared to those who report and challenge racism (Krieger & Sidney, 1996). But perhaps there is a role of structural racism in shaping life histories. Other research using the Millennium Cohort Study has shown that children are affected by their mothers' experience of racism (Y. Kelly, Becares, & Nazroo, 2013).

The ethnicity picture is therefore a complex one, and how it resizes the pie or reallocates its slices is difficult to determine. In so far as being a minority is associated with lower socioeconomic disadvantage, Pakistani women may have fewer resources, and thus a smaller-sized allocation pie. In so far as ethnic minority status predicts the experience of discrimination, the harsher sociocultural environmental experiences may influence how much investment is made in different behavioural domains i.e. by changing the relative size of each of the allocation slices. Where structural racism translates into negative sociocultural environmental experiences, these may be countered to some extent by supportive sociocultural practices fostered by religious and home-country beliefs – there may therefore be some tension over how the slices should be cut or alternatively these two seemingly opposing influences may coincide, agreeing on optimal allocation in the given context.

5.1.4 Different breastfeeding outcomes, different barriers?

As my thesis has shown, breastfeeding behaviour is affected by barriers at multiple levels and of different types. The various barriers of socioeconomic disadvantage, environmental harshness and ethnicity do, however, appear to influence initiation and duration differently. To recap the different influences on these two outcomes[7], Paper 1 found that amongst MCS mothers, SES significantly positively predicted both initiation and duration, as did objective environmental quality. Subjective environmental quality was not significantly associated with initiation and just approached significance in its association with duration (p=0.056). Paper 2 found that chances of both initiating and maintaining breastfeeding lessened with increasing socioeconomic disadvantage for both White British and Pakistani-origin mothers; increased exposure to air pollution was associated with reduced chances of initiation but a *reduced* hazard of stopping breastfeeding and damp/mould exposure was associated with *increased* odds of initiation amongst White British mothers; greater exposure to water chlorination chemicals and air pollution was associated with reduced chances of initiation and greater exposure to one water chlorination chemical, dibromochloromethane, also increased the hazard of stopping breastfeeding amongst Pakistani-origin mothers. Taken together these mixed results do not provide strong evidence for one breastfeeding outcome being more susceptible to socioeconomic, environmental or ethnic influences than another although we can speculate that the decisions to start and continue breastfeeding will nevertheless be susceptible to different constraints.

The most obvious likely constraint relates to mothers having to return to work; several studies have shown that this is a key contributing factor to women's decisions to stop breastfeeding (Arlotti & Cottrell, 1998; Hawkins et al., 2007; Kimbro, 2006; Mirkovic, Perrine, Scanlon, & Grummer-Strawn, 2014; Skafida, 2012). Breastfeeding rates are however counterintuitively better in the US where maternity leave provision is virtually non-existent (Calnen, 2007), perhaps questioning how important structural constraints of this kind really are. The many difficulties mothers experience in establishing breastfeeding (e.g. sore nipples, perceived insufficient milk, mastitis etc. (Wambach & Riordan, 2016)) will no doubt also contribute to the steep drop off in breastfeeding rates

[7] Focussing on significant and borderline significant results of fully-adjusted models.

in the UK. From an evolutionary perspective then, mothers may be choosing to invest in their offspring, but may have to cap the investment provided by lactation due to forces beyond (or perceived to be beyond) their control – suggesting that investment is not necessarily deliberately reduced.

A key aspect not accounted for in my thesis is the role of the infant in shaping infant feeding journeys. Breastfeeding is a dyadic process involving the infant just as much as the mother (Tully & Ball, 2013). My analyses controlled for infant characteristics to a limited extent with birthweight in Paper 1 and the infant's sex, and whether the birth was a singleton or multiple birth in Paper 2. The analyses exploring mediation by gestational age, birthweight, head circumference and abdominal circumference in Paper 2 also addressed the influence of the infant to some extent. Future work addressing the dyadic impact on breastfeeding would, however, benefit from using other breastfeeding outcomes, such as amount of milk transferred per feed and per day, and how often the infant expresses feeding cues.

There are several other aspects of infant feeding behaviour not explored in this thesis such as beliefs, attitudes, intentions, exclusivity, milk yield, and milk energy density. Whilst using different measures such as these could add clarity as to when exactly socioeconomic and environmental differentials emerge in women's infant feeding journeys, it is unlikely that the substantive conclusion, i.e. that increasing disadvantage and harshness reduce parental investment through breastfeeding, would change. Other research that has looked at these different indicators suggests that findings would be similar. For example, a UK study found that lower SES mothers were more likely to view bottle feeding as more convenient, less likely to see breastfeeding as important for bonding, and less likely to intend to exclusively breastfeed for the first three months of life (Beale et al., 2006). The fact that more research links SES to various breastfeeding outcomes than explores environmental drivers does, however, justify an expansion of the research into this thesis to look at environmental links with other breastfeeding outcomes.

5.1.5 Trait clustering and life history strategies

The findings from my third study question the extent to which life history traits form unified strategies both within and across different behavioural domains. The splitting of women, and indeed men, into short- and long-term mating strategists is an assumption of evolutionary psychology that has been criticised. More nuanced approaches acknowledge that women (and probably men) are likely to adopt a mixed strategy, favouring short- or long-term mating strategies in different situations (Smiler, 2011). Whilst environmentally-patterned sex differences in mating and parenting strategies are now relatively well established, my findings highlight that women also exhibit within-individual variation in the patterning of life history traits. The limited clustering both within and between behavioural domains suggests that behavioural flexibility is an important aspect of the life histories of UK mothers.

A more nuanced understanding of life history reflects that mothers will need to make trade-offs, both within and across domains. Resources are finite and so traits cannot all conceivably be "slow", i.e. mothers cannot invest in every domain. Taking parenting as an example, mothers may choose to invest in their child's health and development in one way at the cost of another – time spent reading to a child may detract from time spent breastfeeding (although some mothers may be able to do both at the same time!).

Other research has also thrown into question the extent of life history trait clustering. For example, age at puberty was associated with sexual debut and age at marriage amongst both sexes in a historical USA population, but not with age at first birth or total fertility in a 1946 UK birth cohort (Sheppard, 2014). If different traits show limited correlations within individuals, then how useful is it to describe behaviour as "strategies" and to categorise people into "fast" or "slow" groups? The majority of traits in my third study showed relatively small differences in probabilities and means between the "fast" and "slow" classes across the four groups, suggesting that women with different life history strategies did not actually differ that much from one another. Perhaps it results from a human desire to categorise the world around us to help make sense of everything, but humans are not that simple. We, like other species, are complex creatures who adopt flexible behavioural strategies in response to environmental conditions and resource access. A simplistic division of women (and men) into fast or slow strategists does not adequately account for our developmental plasticity and behavioural flexibility (Dunkel, Mathes, & Decker, 2010). Researchers therefore need to allow for movement on the life history strategy continuum and expect variation in the extent to which different traits pattern together. We also need to consider carefully which variables should be used to index life history strategy, focussing on reliable indicators and avoiding over-extrapolation to less informative indicators.

5.2 REFLECTIONS ON RESEARCH METHODS

A mixed-methods approach to research has many benefits. It enables the researcher to triangulate findings and to utilise the relative strengths of different research approaches. Qualitative research can add clarification to confusing quantitative results whilst quantitative analysis literally enumerates the problem at hand: both important elements to truly understanding a research problem. Feasibility and funding restrictions on PhD research can limit the variety of research methods employed. The shape of my project has evolved extensively since its inception, shifting from an initial desire to analyse the constituents of breast milk in a laboratory, to wanting to conduct focus groups with women, and then settling on the quantitative analysis of secondary datasets. At the beginning of my PhD I believed I could do some initial secondary data quantitative data analysis to inform later qualitative research. My number crunching became my fieldwork. To truly know a dataset takes time, much more time than I thought. I have gained advanced quantitative data analysis skills through this research endeavour but would like to give brief attention to the pros and cons of different research approaches here, but first I discuss the assumptions needed for causal interpretations of my findings.

5.2.1 Assumptions needed for causal interpretation of the findings

My analyses test for associations between environmental exposures and breastfeeding (and other parenting, reproductive and health behaviours) with the assumption that the former causes the latter, although with the caveat that these are just tentative causal associations given the data type and quality available.

The gold standard for testing causality is randomised controlled trials but these are not appropriate for my research interests as it would be unethical to deliberately expose women to harsh environmental conditions. Natural experiments would be a fruitful way to examine environmental-breastfeeding links, for example exploring instances where some mothers are exposed to acute environmental dangers such as natural disasters whilst others aren't. Of course choosing appropriate comparison groups becomes difficult in this case, but efforts could be made to capture sociodemographically similar women e.g. from the same country but an unaffected area. This approach would perhaps be more suited to exploring environmental impacts outside of the UK, as natural disasters are currently rare in this context. My thesis instead took advantage of two rich cohort datasets to explore my research questions of interest.

There are pros and cons of using cohort data. The two datasets I have used in my thesis are rich sources of information containing lots of variables, but of varying quality. There are likely some measurement error issues, due to questions not capturing accurately the phenomena of interest. This is likely due to both variation in the interpretation of questions by respondents for some variables and limitations of the assessment methods used to create other variables. For example, even the basic breastfeeding questions may be understood differently by different mothers – being taken to mean only at-breast feeding for example, even if breastmilk was given by other means. The pollutant exposure measures whilst individualised to take into account mothers' residence and activity patterns, are still subject to error due to not only issues of recall bias but also extrapolating individualised exposure based on area-based measures (i.e. from water supply zones or air pollution monitoring points). Ideally we would have assurance that questions were valid measurements with prompts and sense-check questions, or better still the use of cognitive interviewing procedures, whilst more accurate means of assessing pollutant exposure could be ascertained with the use of personal monitors. Of course improving the accuracy of each construct in a cohort survey in such a way requires additional support, time and funding and as such we make do with the quality of information available, with the caveat that it is usable but not perfect.

It would be helpful in future primary data collection efforts to try and capture important intervening variables such as physiological assessments of milk composition and transfer as well as questions pertaining to awareness and feelings of environmental threat. Evidence for mediation through such pathways would help to confirm the tentative links found in my thesis and lend support to the plausibility of causation between environmental exposure and breastfeeding outcomes.

Given that causation requires the “cause” to precede the “effect”, one major limitation of my thesis is that whilst it uses cohort data, the analyses are not strictly longitudinal, combining instead variables from different survey waves or cross-sections of time. For example, in some cases I used environmental data from later time points as proxies for earlier exposure. This was necessary as some exposures were not assessed at earlier time points. The assumption made here is that exposure is unlikely to change during this time period, however it is acknowledged that this may not be the case for all respondents. The BiB household condition measures were captured in surveys administered when the cohort children were at least 12 months old. With an average breastfeeding duration of 8-9 months (Table 3.1), many mothers would have stopped breastfeeding before access to central heating and damp/mould exposure were assessed. Similarly, two of the maternal questionnaire items and all of the neighbourhood assessment items in Study 1 were collected in the second wave of the MCS. With a mean breastfeeding duration of just 2.7 months in this sample, environmental exposure data was therefore collected an average of 33.3 months later than mothers stopped breastfeeding. The corresponding gaps between measurements are obviously greater for initiation. Time at current address was controlled for in Study 1, helping to partially avoid the issue of using new environmental information to predict past behaviour. Models restricted to those who had not moved house also gave substantively similar results, suggesting that the use of later environmental exposure as proxies for earlier exposure may not be too problematic. Ideally, relationships between environmental conditions and infant feeding and other behavioural responses would be measured in the appropriate temporal sequence in future work. Primary data collection can be designed to accommodate this, but in secondary data analysis the researcher has no control over what is asked and when.

Confounding is of course a concern in any analysis of cause and effect. Whilst randomisation largely takes control of this in RCTs, observational studies have to control for potential confounders at the analysis stage. My analyses make good attempts at accounting for other explanatory factors, by controlling for several infant and maternal characteristics that have established links with breastfeeding. There is of course the possibility of residual confounding as there may be important contributing variables that I did not control for as well as other factors not measured in the dataset. Notwithstanding these caveats, the fact that at least some of the environmental-breastfeeding associations were robust to controlling for maternal and infant characteristics *and* socioeconomic status, suggests that some aspects of the environment are likely to have real effects on maternal reproductive and parenting behaviour, albeit that the true size of these effects may be smaller than estimated.

5.2.2 Other research methods

I had planned to conduct focus group discussions to better understand how environmental factors impact the constraints (e.g. time, energy, emotional support and social acceptance) that women have to achieving infant feeding goals, and how these vary by sociodemographic characteristics. Focus groups are well-suited to exploring complex issues in health research and also facilitate the collection of rich data at a relatively low cost (McFadden & Toole, 2006, p. 158; Pickett & Pearl, 2001, p. 120). Their merit over in-depth interviews is that they can reveal social norms (Dykes, Moran, Burt, & Edwards, 2003, p. 393) and data is generated through an interactive process (Kitzinger, 1994). They can also facilitate discussions regarding sensitive or embarrassing issues more easily (Kitzinger, 1994), which given pervasive negative views on breastfeeding in public (Lisa Dyson, Green, Renfrew, McMillan, & Woolridge, 2010; Scott & Mostyn, 2003; Twamley et al., 2011), would have made them ideal for discussing breastfeeding practices.

Hailed as the more objective approach, quantitative data analysis is actually not completely free of subjective influence. Statistical analysis is an art, not just a science. As a data analyst, I am still influenced by my world view and inherent biases. Furthermore, as I used secondary data, I had no control over which questions were asked and how they were asked to survey participants. I also had no input on the way data was checked, processed and stored. Whilst I chose datasets based on my research questions, I was limited by the variables available.

Following my own cohort of women pre-pregnancy and until the end of their infant feeding journeys would have been ideal. Designing my own surveys and conducting qualitative interviews with mothers may well have enabled me to capture more relevant data, but primary data collection is a costly and time-consuming endeavour. Secondary data analysis is instead a cost- and time-effective way of testing research questions (and generating new hypotheses). Both datasets in my thesis contain data on thousands of mothers. It would have been impossible for me to collect data on as many women by myself. There is a trade-off between being able to capture the exact data you want and having enough data points to analyse the phenomenon at hand. Reanalysing already collected data also reduces the burden on research participants.

Even though my PhD research came to rely on the analysis of large pre-existing datasets, I thought it was still important to have some insight into the people behind the numbers. Having not yet had children myself, I also felt it was necessary to improve my understanding of breastfeeding. For these reasons I decided to get involved with front-line breastfeeding support. In 2015 I began lactation consultant training and attended eight breastfeeding study days before going on to volunteer at my local La Leche League support group and helping to run antenatal breastfeeding courses throughout 2016 and 2017. These sessions gave me valuable insight into not only the biology of breastfeeding, but also the emotions and complications involved. I met some wonderfully passionate breastfeeding advocates and supporters, and these experiences have no doubt filtered through to my research, even if only in subtle ways. The La Leche League (LLL) women are a select group. They are women who might need some extra nurturance and reassurance, but they are breastfeeding already or, in the case of expectant mums, have high intentions to do so. Volunteering for LLL also helped me to think more about the mothers who weren't at the meetings: the mothers who weren't breastfeeding. A strength of the two datasets I analysed is their inclusion of disadvantaged mothers. The MCS over-sampled in deprived areas (Plewis, 2004) and Bradford is one of the most deprived areas in England (ranked 19th out of 326 local authorities nationally) (City of Bradford Metropolitan Council, 2015).

Being part of the breastfeeding advocacy world showed me how essential individualised mother and infant focussed support is, and my PhD research means in no way to downplay its importance. Rather, I hope that my research shows that there are barriers behind the breastfeeding-specific barriers that shape infant feeding behaviour, and that to successfully improve our country's low breastfeeding rates, we need to provide support at multiple levels – from assisting the mother and infant dyad with latch and positioning, right through to tackling environmental inequities.

5.3 POLICY IMPLICATIONS

Although my findings are complex and nuanced there are clear policy implications. My research has highlighted that in addition to the breastfeeding-specific barriers highlighted by UNICEF (Ashmore, 2016), there are more distal, and sometimes more subtle, influences on women's behaviour: the barriers behind the barriers. A focus on the importance of context, whilst central to a human behavioural ecology approach, also resonates with the recent Jedi Public Health movement. Jedi Public Health calls for changing everyday environments rather than targeting individuals in an effort to reduce health inequities (Geronimus et al., 2016).

It is now well-known that young White women from deprived areas are the least likely to breastfeed (McAndrew et al., 2012). My research has illuminated some of the ways that this disadvantage is created. I have improved upon assessments of area-level deprivation by measuring localised and individualised environmental experiences. I have shown that although the ethnic majority, White UK-born women are particularly susceptible to adverse environmental exposures, perhaps lacking the sociocultural protection afforded by the cultural and religious affiliations of other ethnic groups.

We need to improve the support for women to breastfeed in public. Women who are brave enough to breastfeed in public are judged negatively (Grant, 2016). We also need to address the physical aspects of the environment to render it more supportive of healthful infant feeding practices. This can take several forms – from clearing the streets of dog mess to rethinking our water chemical processes – every step towards making local environments cleaner and safer is a step towards helping mothers and their babies, and likely a step towards improving the health of the rest of the neighbourhood too.

Public Health England sets out four things that need to be done to improve breastfeeding rates (Public Health England & Unicef UK, 2016):

1) Raise awareness that breastfeeding matters;
2) Provide effective professional support to mothers and their families;
3) Ensure that mothers have access to support, encouragement and understanding in their community; and
4) Restrict the promotion of formula milks and baby foods.

My work suggests that there is one more way in which policy can help:

5) Address the broader environmental issues that are patterning reproductive and parenting behaviour

Early life experiences play a key role in shaping health and behaviour but environmental interventions are not limited to changing childhood exposure. Importantly, this thesis has also shown that changes to adult environments can still make a difference and it is never too late to intervene.

5.4 DISSEMINATION AND FUTURE WORK

I have presented the three papers in this thesis at several conferences. Because I consider the sharing of ideas across disciplines to be important, I ensured I discussed my ideas in different forums – from conferences aimed at evolutionary audiences, to those focusing on infant nutrition, to those connecting secondary data analysts working on health studies. These different forums provided valuable feedback and helped me to communicate my ideas and findings more effectively.

This is a thesis by publication and at present the three papers are at various stages in the publication process. I have targeted journals from different disciplines to increase cross-fertilisation of ideas and research impact. I have written a blog post about my first study[8] and have been asked by the UK Data Service's Impact Team to write another blog[9] and case-study[10] about my research, both of which I hope will increase the impact of my research.

There are several potential avenues for future research. During my PhD studies I have had an insight into policy through my work at Public Health England. I have further developed my research skills working on a project at LSE looking at age at first period in low- and middle-income countries and have broadened my knowledge through teaching Key Concepts in Global Health at King's. I have gained some fieldwork experience collecting baseline data for a trial in secondary schools. Volunteering in breastfeeding support groups and providing community sexual health outreach work has helped to ground me throughout[11]. I hope to continue working in population health and I am keen to expand my research focus into low- and middle-income countries where environmental quality will be different from the high-income context of the UK, and outwards from breastfeeding to other aspects of reproduction and parenting. The various experiences of the last four years have consolidated my passion for reducing health inequalities through research, teaching and front-line community work.

5.5 CONCLUSIONS

What began as a project to understand variation in breastfeeding evolved into a project more about understanding the role of the environment. More specifically, I have explored what constitutes environmental quality in a thorough and holistic way. In doing so I have shown that socioeconomic disadvantage and environmental harshness are not one and the same, and that ethnicity adds yet another axis of variation. This nuance highlights the flaws in current life history work and cautions against using SES, environmental quality and ethnicity interchangeably. Each exerts their own influence on breastfeeding (and other parenting and reproductive behaviours) and should therefore not be used as proxies for one another. My work also echoes intersectional approaches, showing that these three axes intersect to create pockets of disadvantage, rendering

[8] https://laurajbrown88.wixsite.com/ljbrown/single-post/2016/11/30/THE-UK%E2%80%99S-BREASTFEEDING-PROBLEM-A-SOCIETAL-ISSUE-WITH-AN-ENVIRONMENTAL-SOLUTION
[9] http://blog.ukdataservice.ac.uk/environment-breastfeeding/
[10] https://beta.ukdataservice.ac.uk/impact/case-studies/case-study?id=251
[11] More detail on each of these formative experiences is provided in Appendix D

some mothers in particular need of intervention to help them begin and continue breastfeeding. Infant feeding continues to be a contentious issue in the UK. It is an issue that affects everyone, not just mothers, and as such, policy needs to address the multiple layers of environmental influence. This involves not just tailored and individualised support for mothers, but also micro-, meso- and macro-level interventions. Breastfeeding is a societal issue, with an environmental solution.

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APPENDICES

A. SUPPLEMENTARY MATERIAL FOR STUDY 1

A.1 Methods – additional detail

Table A.1: Factor analysis item details

Source	Item	Question	Response options
S1 MAIN	Support sought since birth	I'd like to ask you about other kinds of support you've had for yourself, your baby or your family. Have you turned to any of the following for help or support since [child's name] was born?	GP (doctor)[1] Health Visitor[1] Religious group Drop-in centre for families[1] Telephone advice line[1] No, none of these
S1 MAIN	Frequency spends time with friends	In the past week, how often have you spent time with friends?	Every day 3-6 times 1-2 times Not at all[2] No friends[2]
S1 MAIN	Other parents can talk to	There are other parents I can talk to about my experiences	Strongly agree[3] Agree[3] Neither agree nor disagree Disagree[4] Strongly disagree[4] Can't say[5]
S1 MAIN	Noisy neighbours	How common is noisy neighbours or loud parties?	Very common Fairly common Not very common Not at all common
S1 MAIN	Racist insults or attacks	How common is insults or attacks to do with someone's race or colour?	Very common Fairly common Not very common Not at all common
S1 MAIN	Any places where children can play safely	Are there any places in your area where children can play safely?	No Yes
S1 MAIN	Feelings about neighbour friendliness	Please choose the phrase that you feel applies to most of your neighbours	Very friendly[6] Friendly[6] Neither friendly nor unfriendly Unfriendly[7] Very unfriendly[7] Can't say[8] Don't know[8] Not applicable[8]
S1 MAIN	Access to garden	Do you have access to a garden? Is that for your sole use or shared with anyone else?	No Yes, shared use Yes, sole use
S1 MAIN	Central heating in house	What kind of heating do you use?[9]	Central heating No heating[10] Coal fires[10] Wood fires or stoves Gas fires[10] Electric fires[10] Paraffin heaters[10] Other[10]
S1 MAIN	Damp or condensation	Is there every any damp or condensation on the walls in your home?	Yes No

S1 MAIN	Satisfaction with home	Which of these phrases best describes how you feel about your home?	Very dissatisfied Faily dissatisfied Neither satisfied nor dissatisfied Fairly satisfied Very satisfied
S1 MAIN	Rubbish and litter	How common is rubbish or litter lying around?	Very common Fairly common Not very common Not at all common
S1 MAIN	Vandalism and damage to property	How common is vandalism or deliberate damage to property?	Very common Fairly common Not very common Not at all common
S1 MAIN	Poor public transport	How common is poor public transport?	Very common Fairly common Not very common Not at all common
S1 MAIN	Food shops in easy access	How common is food shops and supermarkets that are easy to get to?	Very common Fairly common Not very common Not at all common
S1 MAIN	Pollution, grime, environmental problems	How common is pollution, grime or other environmental problems?	Very common Fairly common Not very common Not at all common
S1 MAIN	Satisfaction with area	How satisfied or dissatisfied are you with the area you live in. By your area, I mean within about a mile or 20 minutes walk of here?	Very dissatisfied Fairly dissatisfied Neither satisfied nor dissatisfied Fairly satisfied Very satisfied
S2 MAIN	How safe feel in area	Which of these phrases best describes how safe you feel the area you live in is?	Very unsafe Fairly unsafe Neither safe nor unsafe Fairly safe Very safe
S2 MAIN	Good area to bring up children	Is this a good area to bring up children?	Very poor Poor Average Good Excellent
S2 NA	General condition of buildings on the street	How would you rate the general condition of most of the residences or other buildings in the street?	Well kept, good repair & exterior surfaces Fair condition Poor condition, peeling paint, broken windows Badly deteriorated
S2 NA	Security blinds etc.	Do any of the fronts of residential or commercial units have metal security blinds, gates, or iron bars & grilles?	None Some Most
S2 NA	Volume of traffic	How would you rate the volume of traffic on the street?	No traffic permitted Light Moderate Heavy
S2 NA	Burnt out cars on the street	Are there any abandoned or burnt-out cars on the street?	Yes No

S2 NA	Litter etc. in the street or on the pavement	Is there any of the following: rubbish, litter, broken glass, drug related items, beer cans etc, cigarette ends or discarded packs - in the street or on the pavement?	None or almost none Yes, some Yes, just about everywhere you look
S2 NA	Dog mess on the pavement	Is there dog mess on the pavement?	None Some A lot
S2 NA	Graffiti on walls or in public spaces	Is there any graffiti on walls or on public spaces like bus shelters, telephone boxes or notice boards?	No A little A lot
S2 NA	Evidence of vandalism	Is there any evidence of vandalism such as broken glass from car windows, bus shelters, telephone boxes?	No Yes
S2 NA	Arguing or fighting on the street	Are there any adults or teenagers in the street or on the pavements arguing, fighting, drinking, or behaving in any kind of hostile or threatening way?	No–one seen in the street or pavement None observed behaving in hostile ways Yes, one or two arguing etc.[11] Yes, at least one group of three or more[11]
S2 NA	Observer feeling in the street	How did you feel parking, walking, waiting at the door in the street?	Very comfortable, can imagine living/ shopping here Comfortable - a safe and friendly place Fairly safe and comfortable I would be uncomfortable living/ working/shopping here I felt like an outsider, looked on suspiciously I felt afraid for my personal safety

S1 MAIN: mothers' answers to main survey carried out when child was ~ 9 months old. S2 MAIN: mothers' answers to main survey carried out when child was ~ 3 years old. S2 NA: second survey neighbourhood observations. [1] Combined as 'Support sought'. [2] Combined as 'Not at all'. [3] Combined as 'Agree'. [4] Combined as 'Disagree'. [5] Treated as missing. [6] Combined as 'Friendly'. [7] Combined as 'Unfriendly'. [8] Combined as 'NA / Don't know / Can't say' . [9] Interviewer told do not count if does not work. 10 Combined as 'No central heating'. [11] Combined as 'At least one or two people seen arguing etc.'

A.2 Results – additional detail

Table A.2: Descriptives for remaining variables used in analyses

		Breastfeeding	
	n	**Initiation (n(%))**	**Duration in months (Mean (SD))**
Environmental quality:			
Items that did not load on to two main measures:			
Support sought since birth* **			
No support sought	5,988	3,812 (63.67%)	2.34 (3.35)
Support sought	8,576	6,299 (73.46%)	2.95 (3.57)
How often spent time with friends in the last week* **			
Not at all	4,205	2,865 (68.15%)	2.54 (3.43)
1-2 times	6,374	4,555 (71.47%)	2.71 (3.44)
3-6 times	2,567	1,871 (72.89%)	3.18 (3.71)
Everyday	1,417	819 (57.80%)	2.26 (3.40)
Other parents to talk to* **			
Disagreed	1,562	1,029 (65.92%)	2.27 (3.27)
Neither agreed nor disagreed	1,097	717 (65.36%)	2.13 (3.20)
Agreed	11,173	7,862 (70.37%)	2.81 (3.53)

Feelings about neighbour friendliness* **			
NA / Don't know / Can't say	734	518 (71.45%)	2.92 (3.65)
Unfriendly	372	224 (60.22%)	2.21 (3.29)
Neither friendly nor unfriendly	1,852	1,311 (70.83%)	2.55 (3.43)
Friendly	11,618	8,061 (69.39%)	2.72 (3.50)
Central heating in house* **			
No central heating	1,378	855 (62.05%)	2.25 (3.39)
Central heating	13,176	9,250 (70.21%)	2.75 (3.50)
Poor public transport*			
Very common	1,433	1,007 (70.27%)	2.53 (3.42)
Fairly common	2,159	1,535 (71.10%)	2.56 (3.48)
Not very common	4,839	3,303 (68.27%)	2.61 (3.44)
Not at all common	4,581	3,100 (67.69%)	2.79 (3.53)
Food shops and supermarkets that are easy to get to*			
Not at all common	818	548 (66.99%)	2.53 (3.42)
Not very common	1,352	931 (68.86%)	2.56 (3.48)
Fairly common	4,381	2,986 (68.17%)	2.61 (3.44)
Very common	7,994	5,631 (70.45%)	2.79 (3.53)
Volume of traffic			
Heavy	652	469 (72.04%)	3.05 (3.67)
Moderate	2,053	1,415 (68.99%)	2.76 (3.57)
Light	10,679	7,413 (69.45%)	2.67 (3.47)
No traffic permitted	761	508 (66.93%)	2.53 (3.45)
Exposure to current environment:			
Time at current address (years)* **			
Less than a year	2,706	1,731 (63.99%)	2.13 (3.24)
1 to 5 years	7,699	5,538 (71.94%)	2.84 (3.53)
5 to 40 years	4,143	2,832 (68.36%)	2.81 (3.55)
Moved house between waves* **			
No	10,033	7,063 (70.46%)	2.81 (3.55)
Yes	4,365	2,933 (67.22%)	2.44 (3.34)
Unknown	178	118 (66.29%)	2.63 (3.49)
Infant and maternal characteristics:			
Parents/carers in household* **			
One	2,222	1,113 (50.11%)	1.43 (2.75)
Two	12,354	9,001 (72.92%)	2.93 (3.56)
Mother's age at baby's birth in years* **			
14 to 19	1,087	480 (44.36%)	0.89 (2.16)
20 to 29	6,596	4,333 (65.72%)	2.11 (3.16)
30 to 39	6,552	5,024 (76.70%)	3.50 (3.72)
40 to 48	336	273 (81.49%)	4.48 (4.01)
Number of other children* **			
None	6,041	4,476 (74.18%)	2.60 (3.38)
One	5,128	3,488 (68.05%)	2.80 (3.52)
Two	2,263	1,441 (63.70%)	2.71 (3.60)
Three to nine	1,144	709 (62.03%)	2.79 (3.74)
Baby's birthweight* **			
Low (<2,500 g)	907	612 (67.48%)	2.07 (3.06)
Normal (2,500-4,000 g)	12,005	8,275 (68.93%)	2.69 (3.49)
High (>4,000g)	1,644	1,219 (74.15%)	3.11 (3.66)
Baby's ethnicity* **			
White	12,223	8,115 (66.41%)	2.50 (3.40)
Black or Black British	437	407 (93.14%)	4.66 (3.65)
Indian, Pakistani or Bangladeshi	1,294	1,067 (82.46%)	3.22 (3.65)
Mixed or Other	591	509 (86.13%)	4.28 (3.95)
Mother's immigration status* **			
Born in the UK and both parents born in the UK	10,907	7,153 (65.61%)	2.43 (3.37)
Second generation (at least one parent born outside UK)	1,462	1,163 (79.66%)	3.19 (3.63)
First generation (arrived to UK as a child)	695	579 (83.31%)	3.52 (3.65)
First generation (arrived to UK as an adult)	1,188	1,028 (86.62%)	4.37 (3.84)
Language spoken at home* **			
English only	12,523	8,388 (67.02%)	2.53 (3.41)
English and other language(s)	1,539	1,290 (83.93%)	3.78 (3.80)
Other language(s) only	514	436 (85.16%)	3.68 (3.86)
Ward-level contextual factors:			

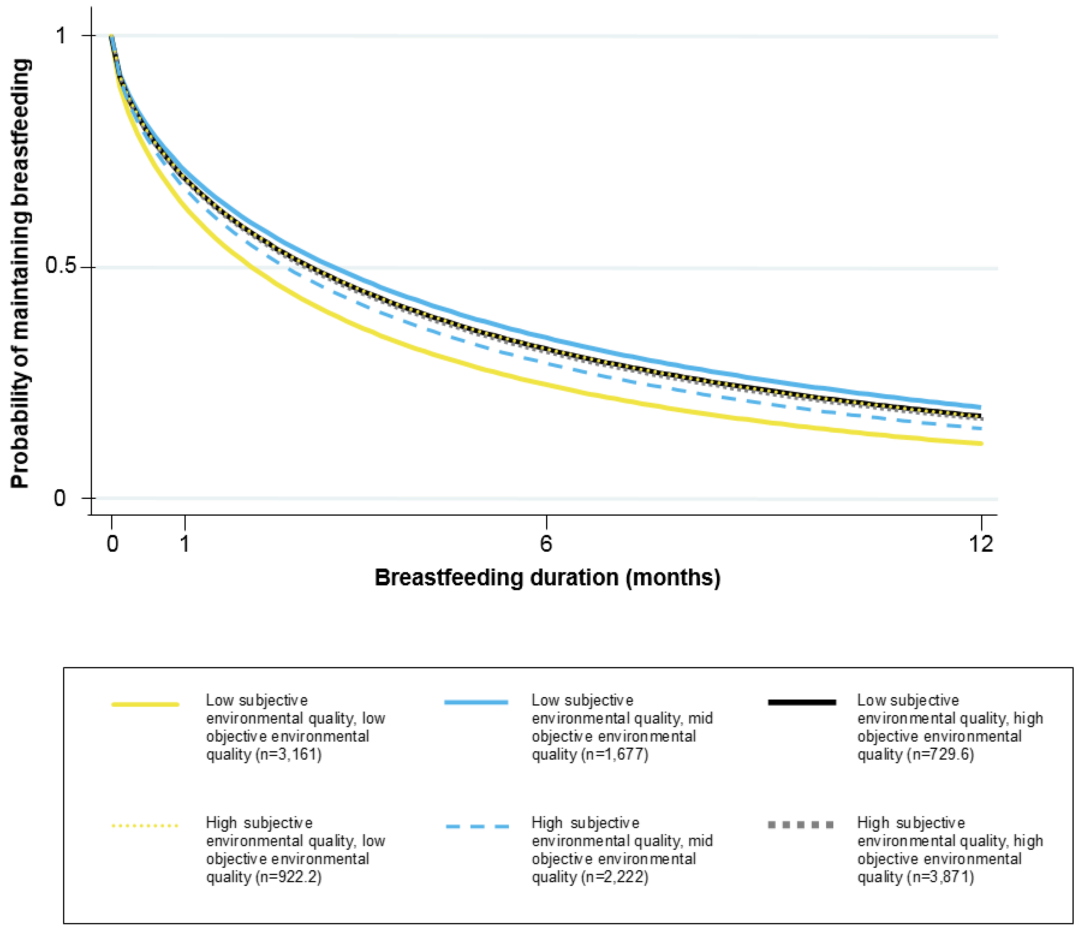
BME proportion* **			
0%	3,757	2,310 (61.50%)	2.17 (3.29)
0-5%	1,880	1,195 (63.63%)	2.39 (3.36)
5-30%	5,986	4,207 (70.33%)	2.73 (3.47)
30-50%	681	524 (77.06%)	3.29 (3.73)
>50%	2,272	1,878 (82.77%)	3.56 (3.71)
Immigrant proportion* **			
0%	642	401 (62.46%)	2.40 (3.44)
0-5%	898	557 (62.10%)	2.10 (3.16)
5-30%	9,300	6,178 (66.47%)	2.49 (3.41)
30-50%	1,282	948 (74.00%)	3.04 (3.60)
>50%	2,454	2,030 (82.82%)	3.59 (3.72)
Non-English speaker proportion* **			
0%	3,006	1,863 (62.02%)	2.25 (3.33)
0-5%	2,581	1,613 (62.59%)	2.29 (3.29)
5-30%	6,393	4,539 (71.02%)	2.78 (3.50)
30-50%	936	773 (82.59%)	3.65 (3.72)
>50%	1,660	1,326 (80.02%)	3.28 (3.69)
Urbanicity***			
0%	1,553	1,109 (71.50%)	2.86 (3.50)
0-50%	1,080	793 (73.43%)	3.08 (3.65)
50-90%	1,449	1,051 (72.58%)	2.95 (3.58)
90-100%	6,893	4,961 (72.01%)	2.81 (3.52)
100%	3,601	2,200 (61.16%)	2.20 (3.31)
Deprivation (IMD quintile)* **			
1 - most deprived	2,949	1,836 (62.36%)	2.15 (3.29)
2	2,943	1,863 (63.37%)	2.20 (3.29)
3	2,874	1,845 (64.26%)	2.31 (3.27)
4	2,900	2,168 (74.76%)	3.14 (3.61)
5 - least deprived	2,910	2,402 (82.54%)	3.70 (3.70)

*Unweighted. N=14,576. Pearson Chi^2 comparing proportion initiating breastfeeding across categories: ***p≤0.001.*

A.2.1 Interactions between objective and subjective measures of local environmental quality to predict breastfeeding outcomes

When both objective and subjective measures were included in the same model, the positive relationship between objective environmental quality and breastfeeding initiation increased (1.717, CI 1.346-2.191). Conversely, subjective environmental quality became more strongly negatively associated with breastfeeding initiation once we controlled for objective environmental quality, and the relationship became significant (0.872, CI 0.786-0.968). These patterns were replicated in the other SES model versions. Despite this, we did not find any evidence for an interaction between the two measures in predicting initiation.

Figure A.1: Breastfeeding duration by subjective environmental quality and objective environmental quality



Predicted probabilities from model controlling for exposure to current environment, infant and maternal characteristics, income and ward-level contextual factors and accounting for both fixed and random effects. N=9,321. Interaction p=0.003. All covariates held at mean values. Group ns are weighted counts.

Subjective and objective environmental quality did however interact to predict breastfeeding duration. As Figure A.1 shows, most women initiated breastfeeding but only kept it up for a short while, with the biggest difference between groups emerging after 1 month, and relative differences persisting through to 12 months. Women scoring poorly on both measures had the lowest chances of maintaining breastfeeding. Women in objectively measured mid-quality environments with low subjective environmental quality had the greatest chances of maintaining breastfeeding. Gaps between lines show that subjective environmental quality makes a larger difference to the probability of maintaining breastfeeding in low objective environmental quality areas (yellow lines more spaced out) compared to high objective environmental quality areas (black lines closer together). This interaction persisted in all SES model versions (results not shown).

A.2.2 Results from our models using the extra environmental quality indicators that did not load on to out two main summary measures

A.2.2.1 Support sought

We found evidence of a positive association between seeking support and breastfeeding initiation. Mothers who did not seek support had around three quarters the odds of initiating breastfeeding compared to those who did, even after ward-level contextual factors were accounted for. Although the effects sizes varied depending on which indicator of SES was controlled for (Tables A.4-A.7), all results were in the in the direction we predicted: mothers who did not seek support, i.e. those who had a lower quality sociocultural environment, were less likely to initiate breastfeeding. We found no evidence for an association between support sought and breastfeeding duration.

A.2.2.2 Other parents to talk to

We found no evidence of an association between having other parents to talk to and breastfeeding initiation in any of the SES models, but we did find evidence for a positive association between having other parents to talk to and breastfeeding duration. After adjusting for SES and contextual factors, those who disagreed or neither agreed or disagreed that they had other parents to talk to had similar hazards of stopping breastfeeding to each other, but those who agreed had a 15.3% reduction in the odds of termination (Table A.3). The effect size varied slightly across SES model versions with a low of 13.9% for the education and all SES versions (Table A.7) but remained in the direction we predicted: mothers with no other parents to talk to, i.e. with a lower quality sociocultural environment, were less likely to maintain breastfeeding.

A.2.2.3 Spending time with friends

We found good evidence of a negative association between how often women spent time with their friends in the past week and whether they initiated breastfeeding. There was no difference in odds of initiation across women who spent between no time and six of the last seven days with their friends, the association was instead driven by those who saw their friends every day in the last week. These women were around 21-23% less likely to initiate breastfeeding compared to those who saw their friends 1-2 times that week (Tables A.4-A.7). This goes against our prediction that women with a better quality sociocultural environment are more likely to breastfeed.

How frequently mothers spent time with their friends was even more strongly predictive of breastfeeding duration, but here the association was positive and was driven by the 3-6 times per week group. Those who had no friends or never saw them and those who saw their friends everyday had similar risks of stopping breastfeeding to those who saw their friends 1 or 2 times a week, while those who saw their friends 3-6 times were around 16-17% less likely to stop breastfeeding in the fully adjusted model. This relationship was again robust across all SES model versions (Tables A.4-A.7). This is more in line with what we would predict - assuming that spending more time with friends is indicative of having a better quality sociocultural environment.

A.2.2.4 Neighbour friendliness

We found no evidence to suggest that feelings about neighbour friendliness predicted breastfeeding initiation. However, we did find some weak evidence for a positive association with breastfeeding duration, although p-values increased above conventional levels of statistical significance once SES was added to the model. This association was driven by the decreased hazard of breastfeeding termination for those who rated their neighbours as friendly, as both those who didn't express a judgement and those who rated their neighbours as unfriendly did not differ from those who rated their neighbours as neither friendly nor unfriendly. The relationship was in the direction predicted with mothers who had a better quality sociocultural environment (i.e. friendly neighbours) being more likely to breastfeed for longer. The weak evidence of an association found in the other SES model versions does however call the robustness of this relationship into question.

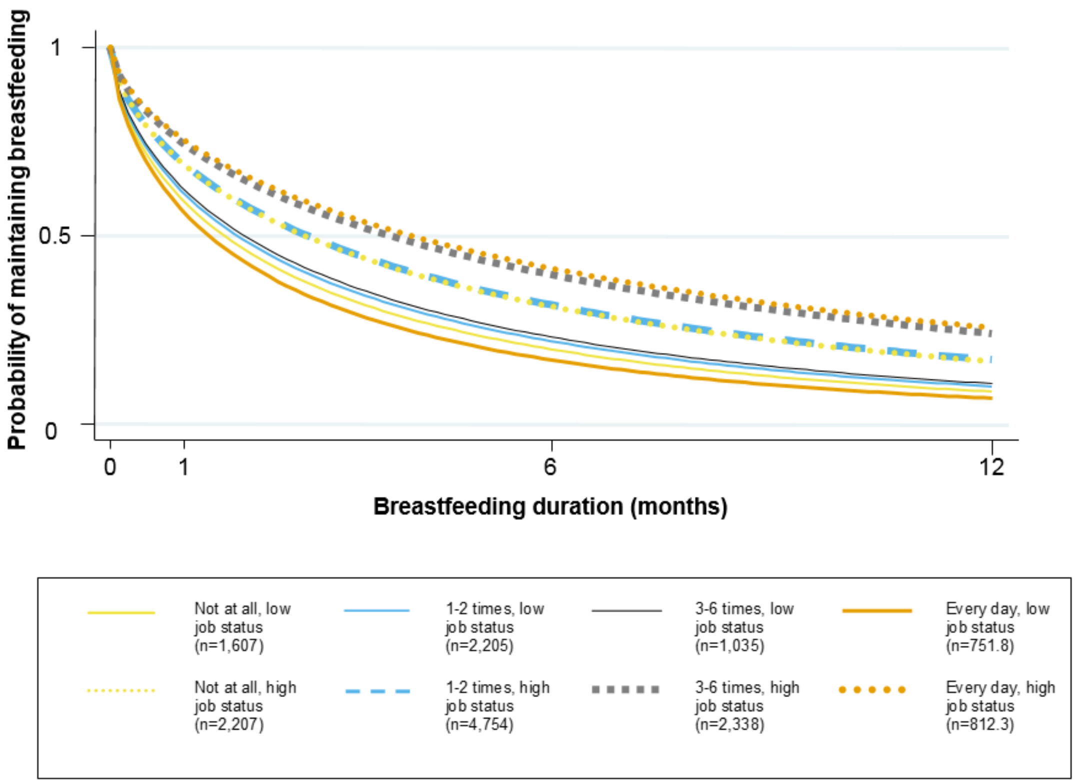
A.2.2.5 Central heating

Whether a mother had central heating was positively associated with breastfeeding initiation in the simplest model, but the association was removed once SES was controlled for. Central heating did however predict duration, but not in the predicted direction (and only once SES was added to the models), with mothers being 13-14% less likely to stop breastfeeding when they had no central heating.

A.2.3 SES interactions with the extra local environmental quality measures

Spending time with friends showed the most pronounced interaction with SES. This variable interacted with all three SES measures. Figure A.2 depicts how the relationship between how often mothers spend time with their friends and breastfeeding duration varies according to job status. Comparing distances between solid and dashed lines, we can see that high SES is less able to mitigate against reduced breastfeeding chances for women who see their friends less often than for women who see their friends regularly. This goes against our hypothesis that high SES will buffer against low environmental quality, as SES appears to have a stronger impact in a situation we would deem indicative of high sociocultural environmental quality (i.e. high level of support from friends).

Figure A.2: Breastfeeding duration by job status and how frequently mother spent time with friends in the last week



Predicted from model controlling for infant and maternal characteristics, job status and ward-level contextual factors. N=9,880. Interaction p<0.001. Those with N/A and mid job status omitted for clarity. All covariates held at mean values. Group ns are weighted counts.

Table A.3: Full objective environmental quality model results (income version)

	Initiation (N=13,737)			Duration (N=9,561)		
	Odds Ratio	**95% Confidence Interval**	**P-value**	**Hazard Ratio**	**95% Confidence Interval**	**P-value**
Objective Environmental Quality	1.537	1.229-1.922	**<0.001**	0.859	0.766-0.965	**0.010**
Moved House between waves			0.194			0.240
No	1.000	(ref.)	.	1.000	(ref.)	.
Yes	0.921	0.794-1.068	0.276	1.054	0.991-1.120	***0.094***
Unknown	0.555	0.243-1.268	0.162	1.068	0.751-1.519	0.714
Time at current address (years)	0.988	0.974-1.001	***0.072***	0.998	0.989-1.007	0.682
Parents/carers in household			**<0.001**			0.485
One parent/carer	1.000	(ref.)	.	1.000	(ref.)	.
Two parents/carers	1.575	1.280-1.939	**<0.001**	0.946	0.810-1.105	0.485
Mother's age at baby's birth in years			**<0.001**			**<0.001**
14 to 19	0.568	0.442-0.731	**<0.001**	1.177	0.958-1.447	0.120
20 to 29	1.000	(ref.)	.	1.000	(ref.)	.
30 to 39	1.439	1.246-1.662	**<0.001**	0.804	0.753-0.858	**<0.001**
40 to 48	2.479	1.557-3.949	**<0.001**	0.652	0.546-0.779	**<0.001**
Number of other children			**<0.001**			**<0.001**
None	1.000	(ref.)	.	1.000	(ref.)	.
one	0.524	0.455-0.604	**<0.001**	0.894	0.835-0.957	**0.001**
two	0.476	0.388-0.585	**<0.001**	0.808	0.723-0.902	**<0.001**
three to nine	0.455	0.361-0.572	**<0.001**	0.701	0.591-0.832	**<0.001**
Baby's birthweight			**0.023**			**0.001**
Low (<2,500g)	0.767	0.588-1.001	***0.051***	1.264	1.113-1.436	**<0.001**
Normal (2,500-4,000g)	1.000	(ref.)	.	1.000	(ref.)	.
High (>4,000g)	1.211	1.000-1.466	***0.050***	0.996	0.903-1.098	0.928
Baby's ethnicity			**<0.001**			**<0.001**
White	1.000	(ref.)	.	1.000	(ref.)	.
Black or Black British	7.984	3.975-16.035	**<0.001**	0.591	0.452-0.773	**<0.001**
Indian, Pakistani or Bangladeshi	0.810	0.460-1.427	0.466	0.906	0.707-1.161	0.436
Mixed or Other	2.141	1.390-3.297	**0.001**	0.708	0.591-0.848	**<0.001**
Mother's immigration status			**0.003**			**0.001**
Born in the UK and both parents born in the UK	1.000	(ref.)	.	1.000	(ref.)	.
Second generation (at least one parent born outside UK)	1.430	1.104-1.853	**0.007**	1.081	0.969-1.207	0.163
First generation (arrived in UK as a child)	1.657	1.141-2.406	**0.008**	0.886	0.744-1.055	0.173
First generation (arrived in UK as an adult)	1.866	1.191-2.924	**0.007**	0.751	0.631-0.894	**0.001**
Language spoken at home			**<0.001**			0.233
English only	1.000	(ref.)	.	1.000	(ref.)	.
English and other language(s)	2.885	1.664-5.002	**<0.001**	0.880	0.729-1.063	0.186

Other language(s) only	2.395	1.276-4.497	**0.007**	0.843	0.667-1.065	0.152
Income (OECD equivalised quintiles)			**<0.001**			**0.002**
Lowest	1.000	(ref.)	.	1.000	(ref.)	.
Second	1.072	0.870-1.322	0.513	0.941	0.821-1.078	0.381
Middle	1.411	1.126-1.768	**0.003**	0.844	0.738-0.966	**0.014**
Fourth	2.006	1.570-2.563	**<0.001**	0.800	0.699-0.916	**0.001**
Highest	2.181	1.587-2.999	**<0.001**	0.782	0.685-0.893	**<0.001**
Ward-level BME proportion			0.271			0.809
0%	1.000	(ref.)	.	1.000	(ref.)	.
0-5%	0.990	0.702-1.395	0.953	1.019	0.882-1.178	0.801
5-30%	0.952	0.699-1.296	0.754	1.031	0.901-1.180	0.659
30-50%	1.619	0.856-3.063	0.139	0.908	0.691-1.192	0.486
>50%	2.419	0.965-6.063	***0.060***	0.846	0.559-1.279	0.427
Ward-level immigrant proportion			0.220			0.841
0%	1.000	(ref.)	.	1.000	(ref.)	.
0-5%	1.394	0.954-2.037	***0.086***	1.004	0.801-1.258	0.973
5-30%	1.390	1.031-1.876	**0.031**	0.946	0.772-1.159	0.589
30-50%	1.261	0.753-2.113	0.378	0.947	0.738-1.215	0.667
>50%	0.917	0.390-2.158	0.843	1.071	0.710-1.614	0.744
Ward-level non-English speaker proportion			0.756			0.815
0%	1.000	(ref.)	.	1.000	(ref.)	.
0-5%	0.977	0.697-1.369	0.890	0.944	0.816-1.093	0.441
5-30%	1.118	0.793-1.576	0.524	0.977	0.848-1.125	0.745
30-50%	1.219	0.670-2.217	0.517	0.882	0.669-1.164	0.376
>50%	0.879	0.386-2.002	0.758	0.804	0.519-1.246	0.329
Ward-level urbanicity			**0.003**			0.453
0%	1.698	1.236-2.332	**0.001**	1.016	0.876-1.178	0.834
0-50%	1.744	1.186-2.565	**0.005**	0.887	0.752-1.046	0.154
50-90%	1.125	0.822-1.540	0.461	1.042	0.900-1.207	0.583
90-100%	1.305	0.986-1.726	***0.062***	1.040	0.928-1.165	0.504
100%	1.000	(ref.)	.	1.000	(ref.)	.
Ward level IMD	1.161	1.122-1.202	**<0.001**	0.964	0.944-0.984	**0.001**
Constant	0.092	0.041-0.206	**<0.001**	1.346	0.898-2.017	0.150
Ward-level variance	0.217	0.139-0.339		0.062	0.041-0.093	
Individual-level variance	3.290			3.953		
Variance partition coefficient	0.062	0.036-0.088	**<0.001**	0.015	0.009-0.021	**<0.001**
/ln_p				-0.44	-0.485--0.391	**<0.001**

Models adjusted for exposure to current environment, infant and maternal characteristics, income and ward-level contextual factors. P-values ≤0.05 shown in bold and p-values between 0.05 and 0.1 shown in bold italic. OECD=Organisation for Economic Co-operation and Development. BME: Black and minority ethnic. IMD: Index of multiple deprivation.

A.2.4 Ward-level variance

As is to be expected, the proportion of total variance due to differences between wards reduced as more variables were added to the models, with the biggest reduction seen between the model adjusting for exposure to current environment, infant and maternal characteristics and SES and the model further adjusting for ward-level factors. Across all sets of models, after accounting for ward-level contextual factors 5.75% of the total variance in breastfeeding initiation was due to unmeasured differences between wards (range 5.31 to 6.31%), while this figure was 1.44% for breastfeeding duration (range 1.33 to 1.48%).

Table A.4: Associations between environmental quality and breastfeeding outcomes (income version)

	Breastfeeding initiation									Breastfeeding termination								
	M1			M2			M3			M1			M2			M3		
	OR	**95% CI**	**P-val.**	**OR**	**95% CI**	**P-val.**	**OR**	**95% CI**	**P-val.**	**HR**	**95% CI**	**P-val.**	**HR**	**95% CI**	**P-val.**	**HR**	**95% CI**	**P-val.**
Subjective Env. Quality	1.125	1.026-1.234	**0.012**	1.014	0.928-1.108	0.759	0.964	0.880-1.057	0.438	0.910	0.864-0.959	**<0.001**	0.933	0.885-0.985	**0.012**	0.947	0.896-1.001	***0.056***
Income (OECD equivalised quintiles)						**<0.001**			**<0.001**						**<0.001**			**<0.001**
Lowest		-		1.000	(ref.)	.	1.000	(ref.)	.		-		1.000	(ref.)	.	1.000	(ref.)	.
Second		-		1.183	0.950-1.474	0.133	1.156	0.929-1.437	0.193		-		0.902	0.787-1.033	0.136	0.905	0.791-1.036	0.149
Middle		-		1.675	1.318-2.128	**<0.001**	1.599	1.263-2.024	**<0.001**		-		0.803	0.705-0.915	**0.001**	0.811	0.712-0.923	**0.002**
Fourth		-		2.532	1.974-3.248	**<0.001**	2.382	1.862-3.046	**<0.001**		-		0.763	0.671-0.868	**<0.001**	0.775	0.682-0.882	**<0.001**
Highest		-		2.947	2.144-4.050	**<0.001**	2.704	1.970-3.710	**<0.001**		-		0.747	0.659-0.847	**<0.001**	0.765	0.673-0.869	**<0.001**
Constant	1.079	0.677-1.718	0.749	1.302	0.842-2.017	0.237	0.354	0.198-0.632	**<0.001**	0.894	0.677-1.181	0.429	0.886	0.664-1.181	0.408	1.054	0.759-1.463	0.754
N	13,866			13,852			13,852			9,631			9,620			9,620		
Objective Env. Quality	2.086	1.651-2.634	**<0.001**	1.670	1.333-2.092	**<0.001**	1.537	1.229-1.922	**<0.001**	0.783	0.703-0.872	**<0.001**	0.841	0.751-0.942	**0.003**	0.859	0.766-0.965	**0.010**
Income (OECD equivalised quintiles)						**<0.001**			**<0.001**						**<0.001**			**0.002**
Lowest		-		1.000	(ref.)	.	1.000	(ref.)	.		-		1.000	(ref.)	.	1.000	(ref.)	.
Second		-		1.093	0.885-1.350	0.407	1.072	0.870-1.322	0.513		-		0.939	0.818-1.077	0.370	0.941	0.821-1.078	0.381
Middle		-		1.471	1.171-1.849	**0.001**	1.411	1.126-1.768	**0.003**		-		0.837	0.732-0.959	**0.010**	0.844	0.738-0.966	**0.014**
Fourth		-		2.125	1.659-2.721	**<0.001**	2.006	1.570-2.563	**<0.001**		-		0.789	0.689-0.903	**0.001**	0.800	0.699-0.916	**0.001**
Highest		-		2.370	1.721-3.263	**<0.001**	2.181	1.587-2.999	**<0.001**		-		0.765	0.672-0.871	**<0.001**	0.782	0.685-0.893	**<0.001**
Constant	0.193	0.087-0.426	**<0.001**	0.312	0.146-0.669	**0.003**	0.092	0.041-0.206	**<0.001**	1.275	0.900-1.808	0.172	1.109	0.773-1.592	0.575	1.346	0.898-2.017	0.150
N	13,752			13,737			13,737			9,573			9,561			9,561		

Support sought since birth																		
No support sought	0.747	0.654-0.854	**<0.001**	0.749	0.655-0.855	**<0.001**	0.752	0.658-0.859	**<0.001**	1.050	0.989-1.114	0.110	1.043	0.983-1.108	0.165	1.043	0.982-1.107	0.171
Support sought	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.
Income (OECD equivalised quintiles)						**<0.001**			**<0.001**						**<0.001**			**<0.001**
Lowest		-		1.000	(ref.)	.	1.000	(ref.)	.		-		1.000	(ref.)	.	1.000	(ref.)	.
Second		-		1.190	0.959-1.476	0.114	1.156	0.934-1.432	0.183		-		0.901	0.786-1.032	0.132	0.907	0.792-1.037	0.153
Middle		-		1.708	1.343-2.172	**<0.001**	1.608	1.270-2.037	**<0.001**		-		0.790	0.694-0.898	**<0.001**	0.802	0.705-0.912	**0.001**
Fourth		-		2.585	2.029-3.295	**<0.001**	2.383	1.875-3.029	**<0.001**		-		0.745	0.656-0.847	**<0.001**	0.763	0.671-0.868	**<0.001**
Highest		-		2.993	2.167-4.134	**<0.001**	2.686	1.947-3.704	**<0.001**		-		0.727	0.644-0.821	**<0.001**	0.750	0.662-0.850	**<0.001**
Constant	2.181	1.729-2.750	**<0.001**	1.625	1.258-2.098	**<0.001**	0.354	0.229-0.549	**<0.001**	0.569	0.438-0.671	**<0.001**	0.638	0.533-0.764	**<0.001**	0.822	0.636-1.062	0.134
N	14,185			14,170			14,170			9,881			9,869			9,869		
How often spent time with friends in the last week			**0.005**			**0.043**			**0.046**			**<0.001**			**<0.001**			**<0.001**
Not at all	0.860	0.724-1.020	***0.084***	0.907	0.767-1.072	0.252	0.909	0.769-1.073	0.259	0.982	0.915-1.055	0.622	0.971	0.903-1.043	0.419	0.969	0.902-1.041	0.394
1-2 times	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.
3-6 times	1.073	0.903-1.276	0.422	1.062	0.893-1.264	0.493	1.057	0.889-1.257	0.528	0.826	0.762-0.896	**<0.001**	0.827	0.762-0.897	**<0.001**	0.829	0.765-0.899	**<0.001**
Everyday	0.744	0.603-0.918	**0.006**	0.781	0.628-0.971	**0.026**	0.780	0.628-0.969	**0.025**	0.919	0.807-1.048	0.207	0.912	0.801-1.039	0.166	0.914	0.803-1.042	0.178
Income (OECD equivalised quintiles)						**<0.001**			**<0.001**						**<0.001**			**<0.001**
Lowest		-		1.000	(ref.)	.	1.000	(ref.)	.		-		1.000	(ref.)	.	1.000	(ref.)	.
Second		-		1.181	0.955-1.462	0.125	1.148	0.930-1.417	0.200		-		0.909	0.792-1.043	0.172	0.915	0.798-1.048	0.199

Middle		-		1.680	1.329-2.125	**<0.001**	1.583	1.257-1.995	**<0.001**		-		0.793	0.697-0.903	**<0.001**	0.806	0.708-0.917	**0.001**
Fourth		-		2.547	2.009-3.229	**<0.001**	2.349	1.857-2.972	**<0.001**		-		0.750	0.659-0.853	**<0.001**	0.768	0.675-0.874	**<0.001**
Highest		-		2.915	2.108-4.032	**<0.001**	2.619	1.895-3.618	**<0.001**		-		0.733	0.649-0.829	**<0.001**	0.757	0.668-0.858	**<0.001**
Constant	2.064	1.612-2.642	**<0.001**	1.528	1.166-2.003	**0.002**	0.328	0.208-0.516	**<0.001**	0.613	0.520-0.722	**<0.001**	0.787	0.574-0.819	**<0.001**	0.878	0.676-1.141	0.332
N	14,184			14,169			14,169			9,880			9,868			9,868		
Other parents to talk to			0.909			0.751			0.779			**<0.001**			**<0.001**			**<0.001**
Disagree	1.046	0.794-1.377	0.751	1.106	0.834-1.466	0.484	1.099	0.829-1.456	0.511	1.015	0.868-1.185	0.856	1.017	0.871-1.188	0.827	1.015	0.869-1.185	0.854
Neither agree nor disagree	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.
Agree	1.052	0.836-1.323	0.665	1.031	0.813-1.307	0.802	1.029	0.813-1.301	0.813	0.832	0.729-0.948	**0.006**	0.847	0.744-0.965	**0.013**	0.847	0.744-0.964	**0.012**
Income (OECD equivalised quintiles)						**<0.001**			**<0.001**						**<0.001**			**<0.001**
Lowest		-		1.000	(ref.)	.	1.000	(ref.)	.		-		1.000	(ref.)	.	1.000	(ref.)	.
Second		-		1.258	1.012-1.564	**0.039**	1.220	0.983-1.514	***0.071***		-		0.890	0.769-1.030	0.117	0.898	0.777-1.037	0.144
Middle		-		1.781	1.405-2.258	**<0.001**	1.677	1.328-2.117	**<0.001**		-		0.786	0.685-0.902	**0.001**	0.800	0.697-0.918	**0.002**
Fourth		-		2.671	2.088-3.416	**<0.001**	2.457	1.926-3.133	**<0.001**		-		0.742	0.647-0.851	**<0.001**	0.762	0.663-0.874	**<0.001**
Highest		-		3.171	2.299-4.373	**<0.001**	2.836	2.061-3.903	**<0.001**		-		0.728	0.640-0.829	**<0.001**	0.753	0.660-0.860	**<0.001**
Constant	1.858	1.354-2.549	**<0.001**	1.369	0.990-1.894	***0.058***	0.286	0.176-0.464	**<0.001**	0.662	0.533-0.822	**<0.001**	0.732	0.538-0.918	**0.007**	0.950	0.698-1.266	0.684
N	13,476			13,465			13,465			9,391			9,383			9,383		
Feelings about neighbour friendliness			0.175			0.220			0.223			**0.012**			**0.033**			**0.042**
NA / Don't know / Can't say	0.693	0.492-0.977	**0.036**	0.717	0.505-1.017	***0.062***	0.727	0.514-1.027	***0.071***	1.146	0.920-1.427	0.224	1.139	0.911-1.425	0.252	1.130	0.905-1.411	0.281

Unfriendly	0.769	0.511-1.157	0.208	0.829	0.554-1.241	0.362	0.825	0.551-1.235	0.350	0.902	0.693-1.174	0.443	0.894	0.689-1.160	0.400	0.895	0.690-1.160	0.401
Neither friendly nor unfriendly	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.
Friendly	0.901	0.754-1.077	0.254	0.857	0.712-1.032	0.104	0.852	0.708-1.025	***0.089***	0.901	0.815-0.996	**0.042**	0.917	0.829-1.015	***0.094***	0.918	0.830-1.016	***0.098***
Income (OECD equivalised quintiles)						**<0.001**			**<0.001**						**<0.001**			**<0.001**
Lowest		-		1.000	(ref.)	.	1.000	(ref.)	.		-		1.000	(ref.)	.	1.000	(ref.)	.
Second		-		1.195	0.964-1.480	0.104	1.161	0.939-1.435	0.168		-		0.898	0.784-1.028	0.120	0.904	0.790-1.033	0.138
Middle		-		1.715	1.350-2.179	**<0.001**	1.616	1.277-2.046	**<0.001**		-		0.791	0.695-0.899	**<0.001**	0.802	0.705-0.912	**0.001**
Fourth		-		2.620	2.052-3.346	**<0.001**	2.417	1.897-3.080	**<0.001**		-		0.750	0.661-0.851	**<0.001**	0.767	0.675-0.871	**<0.001**
Highest		-		2.995	2.159-4.155	**<0.001**	2.689	1.941-3.725	**<0.001**		-		0.733	0.650-0.826	**<0.001**	0.755	0.668-0.854	**<0.001**
Constant	2.150	1.642-2.815	**<0.001**	1.655	1.255-2.182	**<0.001**	0.359	0.227-0.569	**<0.001**	0.625	0.515-0.758	**<0.001**	0.690	0.562-0.847	**<0.001**	0.885	0.673-1.162	0.379
N	14,187			14,172			14,172			9,883			9,871			9,871		
Central heating in house																		
No central heating	0.752	0.600-0.942	**0.013**	0.844	0.677-1.053	0.133	0.857	0.688-1.067	0.168	0.908	0.797-1.036	0.152	0.870	0.763-0.991	**0.037**	0.867	0.762-0.987	**0.031**
Central heating	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.
Income (OECD equivalised quintiles)						**<0.001**			**<0.001**						**<0.001**			**<0.001**
Lowest		-		1.000	(ref.)	.	1.000	(ref.)	.		-		1.000	(ref.)	.	1.000	(ref.)	.
Second		-		1.199	0.969-1.483	***0.095***	1.165	0.943-1.438	0.156		-		0.897	0.783-1.028	0.117	0.903	0.789-1.033	0.136
Middle		-		1.708	1.349-2.163	**<0.001**	1.610	1.276-2.032	**<0.001**		-		0.780	0.685-0.888	**<0.001**	0.792	0.696-0.902	**<0.001**
Fourth		-		2.577	2.021-3.284	**<0.001**	2.379	1.871-3.025	**<0.001**		-		0.732	0.644-0.831	**<0.001**	0.749	0.659-0.852	**<0.001**

Highest		-		2.952	2.140-4.072	**<0.001**	2.653	1.926-3.655	**<0.001**		-		0.713	0.632-0.804	**<0.001**	0.736	0.650-0.833	**<0.001**
Constant	2.030	1.617-2.548	**<0.001**	1.490	1.166-1.906	**0.001**	0.320	0.206-0.496	**<0.001**	0.586	0.498-0.689	**<0.001**	0.664	0.556-0.792	**<0.001**	0.851	0.658-1.102	0.222
N	14,186			14,171			14,171			9,882			9,870			9,870		
Poor public transport			0.100			***0.052***			0.185			0.197			0.165			0.208
Very common	1.120	0.881-1.424	0.355	1.158	0.913-1.469	0.227	1.070	0.842-1.360	0.579	0.885	0.781-1.003	***0.056***	0.880	0.779-0.995	**0.042**	0.891	0.787-1.010	***0.071***
Fairly common	1.246	1.005-1.546	**0.045**	1.282	1.029-1.596	**0.027**	1.226	0.983-1.529	***0.070***	0.996	0.909-1.092	0.939	0.993	0.905-1.089	0.886	1.002	0.913-1.100	0.960
Not very common	0.987	0.844-1.155	0.875	0.996	0.850-1.166	0.957	0.982	0.838-1.151	0.823	0.992	0.911-1.080	0.854	0.988	0.905-1.078	0.787	0.995	0.911-1.086	0.908
Not at all common	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.
Income (OECD equivalised quintiles)						**<0.001**			**<0.001**						**<0.001**			**<0.001**
Lowest		-		1.000	(ref.)	.	1.000	(ref.)	.		-		1.000	(ref.)	.	1.000	(ref.)	.
Second		-		1.255	1.006-1.566	**0.044**	1.216	0.977-1.514	***0.080***		-		0.909	0.796-1.038	0.158	0.915	0.802-1.043	0.185
Middle		-		1.825	1.429-2.329	**<0.001**	1.705	1.340-2.170	**<0.001**		-		0.781	0.682-0.896	**<0.001**	0.794	0.692-0.911	**0.001**
Fourth		-		2.826	2.203-3.626	**<0.001**	2.582	2.019-3.303	**<0.001**		-		0.736	0.645-0.840	**<0.001**	0.754	0.660-0.862	**<0.001**
Highest		-		3.498	2.476-4.942	**<0.001**	3.098	2.195-4.371	**<0.001**		-		0.704	0.624-0.795	**<0.001**	0.728	0.643-0.824	**<0.001**
Constant	1.860	1.438-2.407	**<0.001**	1.311	0.987-1.742	***0.061***	0.317	0.183-0.548	**<0.001**	0.611	0.510-0.731	**<0.001**	0.691	0.571-0.836	**<0.001**	0.886	0.677-1.160	0.380
N	12,673			12,659			12,659			8,742			8,731			8,731		
Food shops and supermarkets that are easy to get to			0.230			0.379			0.203			0.246			0.184			0.269
Not at all common	0.931	0.720-1.203	0.583	0.957	0.738-1.241	0.738	0.910	0.702-1.179	0.477	0.872	0.753-1.011	***0.069***	0.868	0.748-1.007	***0.062***	0.881	0.761-1.019	***0.087***
Not very common	0.840	0.692-1.020	***0.078***	0.858	0.707-1.042	0.122	0.826	0.680-1.005	***0.056***	0.965	0.838-1.111	0.617	0.958	0.832-1.103	0.549	0.965	0.836-1.114	0.627

Fairly common	0.894	0.778-1.028	0.116	0.919	0.803-1.052	0.221	0.902	0.788-1.032	0.134	0.969	0.908-1.034	0.342	0.962	0.901-1.026	0.237	0.965	0.904-1.030	0.284
Very common	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.
Income (OECD equivalised quintiles)						**<0.001**			**<0.001**						**<0.001**			**<0.001**
Lowest				1.000	(ref.)	.	1.000	(ref.)	.		-		1.000	(ref.)	.	1.000	(ref.)	.
Second				1.203	0.970-1.492	***0.093***	1.168	0.944-1.446	0.153		-		0.897	0.783-1.027	0.115	0.903	0.789-1.032	0.134
Middle				1.719	1.355-2.180	**<0.001**	1.616	1.279-2.041	**<0.001**		-		0.786	0.691-0.893	**<0.001**	0.797	0.701-0.907	**0.001**
Fourth				2.610	2.051-3.322	**<0.001**	2.405	1.895-3.052	**<0.001**		-		0.740	0.652-0.840	**<0.001**	0.758	0.667-0.861	**<0.001**
Highest				2.991	2.164-4.133	**<0.001**	2.681	1.944-3.697	**<0.001**		-		0.721	0.639-0.814	**<0.001**	0.745	0.658-0.843	**<0.001**
Constant	2.069	1.655-2.587	**<0.001**	1.517	1.191-1.934	**0.001**	0.326	0.212-0.501	**<0.001**	0.595	0.505-0.701	**<0.001**	0.670	0.560-0.802	**<0.001**	0.856	0.664-1.103	0.229
N	14,177			14,162			14,162			9,873			9,861			9,861		
Volume of traffic			0.303			0.315			0.298			0.566			0.432			0.413
Heavy	1.422	0.985-2.051	***0.060***	1.430	0.983-2.079	***0.061***	1.454	0.992-2.133	***0.055***	0.951	0.823-1.099	0.499	0.950	0.822-1.099	0.492	0.945	0.819-1.091	0.440
Moderate	0.974	0.818-1.161	0.773	1.002	0.840-1.195	0.986	1.007	0.844-1.202	0.934	0.945	0.866-1.032	0.206	0.935	0.857-1.021	0.132	0.934	0.856-1.019	0.125
Light	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.
No traffic permitted	1.002	0.761-1.319	0.989	1.027	0.780-1.351	0.851	1.003	0.764-1.315	0.985	0.973	0.863-1.096	0.648	0.961	0.851-1.087	0.529	0.971	0.860-1.095	0.629
Income (OECD equivalised quintiles)						**<0.001**			**<0.001**						**<0.001**			**<0.001**
Lowest		-		1.000	(ref.)	.	1.000	(ref.)	.		-		1.000	(ref.)	.	1.000	(ref.)	.
Second		-		1.164	0.939-1.443	0.167	1.129	0.913-1.396	0.262		-		0.911	0.794-1.045	0.182	0.917	0.800-1.050	0.210
Middle		-		1.682	1.338-2.115	**<0.001**	1.580	1.261-1.978	**<0.001**		-		0.798	0.699-0.911	**0.001**	0.811	0.710-0.926	**0.002**
Fourth		-		2.515	1.967-3.216	**<0.001**	2.313	1.815-2.949	**<0.001**		-		0.745	0.653-0.849	**<0.001**	0.763	0.669-0.871	**<0.001**
Highest		-		2.854	2.065-3.944	**<0.001**	2.549	1.848-3.515	**<0.001**		-		0.718	0.635-0.812	**<0.001**	0.742	0.654-0.843	**<0.001**

Constant	1.961	1.555-2.473	**<0.001**	1.469	1.143-1.887	**0.003**	0.309	0.202-0.472	**<0.001**	0.587	0.497-0.693	**<0.001**	0.657	0.549-0.786	**<0.001**	0.879	0.675-1.145	0.340
N	13,782			13,767			13,767			9,594			9,582			9,582		

Simplified model results, showing only results for local environmental quality measures and income. M1 adjusted for exposure to current environment, infant and maternal characteristics. M2 adjusted for exposure to current environment, infant and maternal characteristics and income. M3 adjusted for exposure to current environment, infant and maternal characteristics, income and ward-level contextual factors. Each model includes one environmental quality measure only. P-values ≤0.05 shown in bold and P-values between 0.05 and 0.1 shown in bold italic. Hazard ratios represent breastfeeding termination rather than duration. The number of observations (N) varies between models due to differing levels of missing data. Results are weighted to allow for the complex survey design and models are hierarchical to control for the clustering at ward-level. OR=Odds Ratio. HR=Hazard Ratio. CI=Confidence Interval. P-val.=P-value. Env.=Environmental. OECD=Organisation for Economic Co-operation and Development.

Table A.5: Associations between environmental quality and breastfeeding outcomes (job status version)

					Breastfeeding initiation									Breastfeeding termination				
		M1			M2			M3			M1			M2			M3	
	OR	95% CI	P-val.	OR	95% CI	P-val.	OR	95% CI	P-val.	HR	95% CI	P-val.	HR	95% CI	P-val.	HR	95% CI	P-val.
Subjective Env. Quality	1.125	1.026-1.234	**0.012**	1.031	0.940-1.130	0.521	0.978	0.889-1.075	0.646	0.910	0.864-0.959	**<0.001**	0.944	0.895-0.995	**0.032**	0.959	0.907-1.013	0.131
Job status (NS-SEC)						**<0.001**			**<0.001**						**<0.001**			**<0.001**
Not applicable		-		1.000	(ref.)	.	1.000	(ref.)	.		-		1.000	(ref.)	.	1.000	(ref.)	.
Routine and manual		-		1.226	0.907-1.657	0.186	1.204	0.889-1.631	0.229		-		1.058	0.857-1.307	0.599	1.057	0.854-1.308	0.609
Intermediate		-		1.740	1.243-2.435	**0.001**	1.685	1.205-2.356	**0.002**		-		0.801	0.647-0.990	**0.040**	0.801	0.646-0.992	**0.042**
Higher managerial, admin and professional		-		2.867	2.053-4.004	**<0.001**	2.703	1.939-3.767	**<0.001**		-		0.716	0.585-0.876	**0.001**	0.723	0.590-0.885	**0.002**
Constant	1.079	0.677-1.718	0.749	1.022	0.605-1.725	0.935	0.271	0.138-0.533	**<0.001**	0.894	0.677-1.181	0.429	0.856	0.607-1.209	0.378	0.987	0.676-1.441	0.947
N	13,866			13,866			13,866			9,631			9,631			9,631		
Objective Env. Quality	2.086	1.651-2.634	**<0.001**	1.680	1.348-2.094	**<0.001**	1.535	1.234-1.909	**<0.001**	0.783	0.703-0.872	**<0.001**	0.873	0.779-0.979	**0.020**	0.893	0.795-1.004	***0.059***
Job status (NS-SEC)						**<0.001**			**<0.001**						**<0.001**			**<0.001**
Not applicable		-		1.000	(ref.)	.	1.000	(ref.)	.		-		1.000	(ref.)	.	1.000	(ref.)	.

Routine and manual		-		1.141	0.829-1.571	0.418	1.124	0.815-1.550	0.476		-		1.030	0.837-1.267	0.782	1.030	0.835-1.269	0.784
Intermediate		-		1.463	1.011-2.119	0.044	1.420	0.981-2.055	*0.063*		-		0.785	0.636-0.968	0.024	0.786	0.636-0.972	0.026
Higher managerial, admin and professional		-		2.457	1.711-3.528	<0.001	2.328	1.623-3.341	<0.001		-		0.696	0.571-0.849	<0.001	0.703	0.576-0.858	0.001
Constant	0.193	0.087-0.426	<0.001	0.269	0.118-0.616	0.002	0.080	0.033-0.196	<0.001	1.275	0.900-1.808	0.172	1.042	0.690-1.573	0.844	1.231	0.786-1.929	0.364
N	13,752			13,752			13,752			9,573			9,573			9,573		
Support sought since birth																		
No support sought	0.747	0.654-0.854	<0.001	0.757	0.661-0.867	<0.001	0.760	0.664-0.869	<0.001	1.050	0.989-1.114	0.110	1.035	0.977-1.096	0.247	1.034	0.976-1.096	0.251
Support sought	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.
Job status (NS-SEC)						<0.001			<0.001						<0.001			<0.001
Not applicable		-		1.000	(ref.)	.	1.000	(ref.)	.		-		1.000	(ref.)	.	1.000	(ref.)	.
Routine and manual		-		1.206	0.905-1.607	0.200	1.182	0.887-1.577	0.254		-		1.050	0.854-1.289	0.645	1.051	0.854-1.293	0.639
Intermediate		-		1.702	1.226-2.363	0.001	1.627	1.173-2.257	0.004		-		0.788	0.638-0.974	0.027	0.793	0.641-0.982	0.033
Higher managerial, admin and professional		-		2.889	2.085-4.003	<0.001	2.679	1.938-3.702	<0.001		-		0.702	0.576-0.856	<0.001	0.714	0.585-0.871	0.001
Constant	2.181	1.729-2.750	<0.001	1.392	0.955-2.031	*0.086*	0.297	0.172-0.512	<0.001	0.569	0.483-0.671	<0.001	0.654	0.513-0.833	0.001	0.815	0.607-1.096	0.176
N	14,185			14,185			14,185			9,881			9,881			9,881		
How often spent time with friends in the last week			0.005			0.028			0.034			<0.001			<0.001			<0.001
Not at all	0.860	0.724-1.020	*0.084*	0.891	0.751-1.057	0.186	0.895	0.755-1.061	0.201	0.982	0.915-1.055	0.622	0.973	0.907-1.044	0.443	0.971	0.905-1.042	0.412
1-2 times	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.
3-6 times	1.073	0.903-1.276	0.422	1.068	0.896-1.272	0.464	1.060	0.891-1.262	0.509	0.826	0.762-0.896	<0.001	0.832	0.766-0.904	<0.001	0.834	0.768-0.906	<0.001

Everyday	0.744	0.603-0.918	0.006	0.777	0.626-0.963	0.021	0.777	0.627-0.964	0.022	0.919	0.807-1.048	0.207	0.912	0.800-1.041	0.171	0.914	0.801-1.043	0.182
Job status (NS-SEC)						<0.001			<0.001						<0.001			<0.001
Not applicable		-		1.000	(ref.)	.	1.000	(ref.)	.		-		1.000	(ref.)	.	1.000	(ref.)	.
Routine and manual		-		1.187	0.885-1.593	0.252	1.166	0.868-1.566	0.307		-		1.060	0.862-1.303	0.583	1.061	0.862-1.307	0.575
Intermediate		-		1.668	1.198-2.322	0.002	1.598	1.149-2.222	0.005		-		0.796	0.643-0.986	0.037	0.801	0.646-0.994	0.044
Higher managerial, admin and professional		-		2.830	2.041-3.926	<0.001	2.630	1.901-3.640	<0.001		-		0.711	0.582-0.868	0.001	0.722	0.591-0.883	0.002
Constant	2.064	1.612-2.642	<0.001	1.330	0.905-1.953	0.146	0.280	0.161-0.486	<0.001	0.613	0.520-0.722	<0.001	0.694	0.546-0.884	0.003	0.862	0.641-1.161	0.329
N	14,184			14,184			14,184			9,880			9,880			9,880		
Other parents to talk to			0.909			0.944			0.948			<0.001			<0.001			<0.001
Disagree	1.046	0.794-1.377	0.751	1.041	0.787-1.377	0.779	1.039	0.786-1.374	0.788	1.015	0.868-1.185	0.856	1.027	0.879-1.200	0.738	1.024	0.876-1.197	0.763
Neither agree nor disagree	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.
Agree	1.052	0.836-1.323	0.665	1.006	0.797-1.268	0.963	1.005	0.799-1.264	0.968	0.832	0.729-0.948	0.006	0.855	0.747-0.979	0.023	0.855	0.747-0.978	0.022
Job status (NS-SEC)						<0.001			<0.001						<0.001			<0.001
Not applicable		-		1.000	(ref.)	.	1.000	(ref.)	.		-		1.000	(ref.)	.	1.000	(ref.)	.
Routine and manual		-		1.153	0.844-1.575	0.370	1.132	0.827-1.549	0.439		-		1.147	0.909-1.448	0.249	1.151	0.910-1.456	0.239
Intermediate		-		1.594	1.129-2.249	0.008	1.522	1.078-2.148	0.017		-		0.858	0.676-1.089	0.209	0.866	0.681-1.101	0.240
Higher managerial, admin and professional		-		2.802	1.989-3.946	<0.001	2.592	1.844-3.645	<0.001		-		0.766	0.612-0.957	0.019	0.780	0.623-0.977	0.030
Constant	1.858	1.354-2.549	<0.001	1.289	0.834-1.991	0.253	0.262	0.145-0.471	<0.001	0.662	0.533-0.822	<0.001	0.681	0.500-0.927	0.014	0.847	0.593-1.210	0.361
N	13,476			13,476			13,476			9,391			9,391			9,391		
Feelings about			0.175			0.243			0.247			0.012			*0.064*			*0.079*

neighbour friendliness																		
NA / Don't know / Can't say	0.693	0.492-0.977	**0.036**	0.731	0.514-1.041	*0.082*	0.742	0.524-1.051	*0.093*	1.146	0.920-1.427	0.224	1.121	0.905-1.390	0.295	1.114	0.900-1.379	0.320
Unfriendly	0.769	0.511-1.157	0.208	0.800	0.528-1.211	0.292	0.799	0.528-1.210	0.290	0.902	0.693-1.174	0.443	0.883	0.674-1.157	0.368	0.884	0.676-1.157	0.369
Neither friendly nor unfriendly	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.
Friendly	0.901	0.754-1.077	0.254	0.864	0.721-1.036	0.114	0.859	0.717-1.029	*0.098*	0.901	0.815-0.996	**0.042**	0.925	0.837-1.024	0.132	0.927	0.838-1.025	0.140
Job status (NS-SEC)						**<0.001**			**<0.001**						**<0.001**			**<0.001**
Not applicable		-		1.000	(ref.)	.	1.000	(ref.)	.		-		1.000	(ref.)	.	1.000	(ref.)	.
Routine and manual		-		1.179	0.880-1.579	0.269	1.158	0.863-1.552	0.328		-		1.052	0.857-1.291	0.628	1.052	0.856-1.294	0.627
Intermediate		-		1.676	1.207-2.327	**0.002**	1.605	1.157-2.227	**0.005**		-		0.791	0.640-0.977	**0.030**	0.795	0.643-0.984	**0.035**
Higher managerial, admin and professional		-		2.852	2.056-3.957	**<0.001**	2.650	1.914-3.669	**<0.001**		-		0.708	0.581-0.863	**0.001**	0.718	0.589-0.876	**0.001**
Constant	2.150	1.642-2.815	**<0.001**	1.445	0.973-2.147	*0.068*	0.306	0.174-0.538	**<0.001**	0.625	0.515-0.758	**<0.001**	0.699	0.538-0.909	**0.008**	0.869	0.638-1.183	0.373
N	14,187			14,187			14,187			9,883			9,883			9,883		
Central heating in house																		
No central heating	0.752	0.600-0.942	**0.013**	0.837	0.665-1.053	0.129	0.853	0.679-1.071	0.172	0.908	0.797-1.036	0.152	0.872	0.765-0.994	**0.041**	0.869	0.763-0.988	**0.033**
Central heating	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.
Job status (NS-SEC)						**<0.001**			**<0.001**						**<0.001**			**<0.001**
Not applicable		-		1.000	(ref.)	.	1.000	(ref.)	.		-		1.000	(ref.)	.	1.000	(ref.)	.
Routine and manual		-		1.203	0.900-1.607	0.212	1.179	0.881-1.577	0.268		-		1.059	0.862-1.301	0.586	1.060	0.862-1.305	0.580
Intermediate		-		1.696	1.223-2.353	**0.002**	1.623	1.171-2.249	**0.004**		-		0.793	0.642-0.980	**0.032**	0.798	0.645-0.988	**0.038**

Higher managerial, administrative and professional		-		2.865	2.064-3.976	**<0.001**	2.661	1.922-3.684	**<0.001**		-		0.701	0.575-0.855	**<0.001**	0.713	0.584-0.870	**0.001**
Constant	2.030	1.617-2.548	**<0.001**	1.287	0.886-1.871	0.185	0.271	0.157-0.468	**<0.001**	0.586	0.498-0.689	**<0.001**	0.670	0.527-0.852	**0.001**	0.834	0.620-1.121	0.229
N	14,186			14,186			14,186			9,882			9,882			9,882		
Poor public transport			0.100			0.104			0.269			0.197			0.253			0.305
Very common	1.120	0.881-1.424	0.355	1.116	0.880-1.417	0.365	1.035	0.815-1.314	0.781	0.885	0.781-1.003	***0.056***	0.891	0.787-1.009	***0.069***	0.902	0.795-1.023	0.109
Fairly common	1.246	1.005-1.546	**0.045**	1.282	1.026-1.602	**0.029**	1.228	0.981-1.537	***0.073***	0.996	0.909-1.092	0.939	0.995	0.906-1.092	0.909	1.004	0.914-1.103	0.933
Not very common	0.987	0.844-1.155	0.875	1.012	0.863-1.186	0.884	0.997	0.850-1.170	0.974	0.992	0.911-1.080	0.854	0.986	0.904-1.076	0.752	0.993	0.909-1.084	0.870
Not at all common	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.
Job status (NS-SEC)						**<0.001**			**<0.001**						**<0.001**			**<0.001**
Not applicable		-		1.000	(ref.)	.	1.000	(ref.)	.		-		1.000	(ref.)	.	1.000	(ref.)	.
Routine and manual		-		1.222	0.910-1.639	0.182	1.208	0.898-1.624	0.212		-		1.054	0.849-1.308	0.633	1.056	0.850-1.313	0.621
Intermediate		-		1.774	1.266-2.487	**0.001**	1.699	1.212-2.383	**0.002**		-		0.810	0.644-1.019	***0.073***	0.818	0.649-1.029	***0.087***
Higher managerial, admin and professional		-		3.143	2.248-4.394	**<0.001**	2.915	2.085-4.075	**<0.001**		-		0.701	0.567-0.867	**0.001**	0.714	0.577-0.884	**0.002**
Constant	1.860	1.438-2.407	**<0.001**	1.125	0.754-1.679	0.564	0.260	0.137-0.492	**<0.001**	0.611	0.510-0.731	**<0.001**	0.698	0.535-0.910	**0.008**	0.872	0.637-1.193	0.391
N	12,673			12,673			12,673			8,742			8,742			8,742		
Food shops and supermarkets that are easy to get to			0.230			0.349			0.195			0.246			0.254			0.359
Not at all common	0.931	0.720-1.203	0.583	0.950	0.737-1.225	0.692	0.907	0.703-1.170	0.452	0.872	0.753-1.011	***0.069***	0.873	0.751-1.016	***0.079***	0.886	0.764-1.028	0.111
Not very common	0.840	0.692-1.020	***0.078***	0.851	0.701-1.034	0.105	0.823	0.676-1.001	***0.052***	0.965	0.838-1.111	0.617	0.961	0.834-1.108	0.587	0.970	0.839-1.120	0.675

Fairly common	0.894	0.778-1.028	0.116	0.911	0.791-1.049	0.196	0.895	0.777-1.031	0.124	0.969	0.908-1.034	0.342	0.969	0.908-1.034	0.343	0.972	0.911-1.037	0.392
Very common	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.
Job status (NS-SEC)						<0.001			<0.001						<0.001			<0.001
Not applicable		-		1.000	(ref.)	.	1.000	(ref.)	.		-		1.000	(ref.)	.	1.000	(ref.)	.
Routine and manual		-		1.186	0.885-1.590	0.253	1.161	0.866-1.558	0.319		-		1.053	0.855-1.296	0.630	1.054	0.854-1.300	0.624
Intermediate		-		1.684	1.211-2.341	0.002	1.608	1.158-2.232	0.005		-		0.789	0.637-0.978	0.031	0.794	0.640-0.986	0.037
Higher managerial, admin and professional		-		2.861	2.058-3.977	<0.001	2.649	1.910-3.672	<0.001		-		0.703	0.574-0.859	0.001	0.714	0.583-0.875	0.001
Constant	2.069	1.655-2.587	<0.001	1.332	0.918-1.931	0.131	0.281	0.164-0.481	<0.001	0.595	0.505-0.701	<0.001	0.679	0.529-0.871	0.002	0.841	0.624-1.132	0.252
N	14,177			14,177			14,177			9,873			9,873			9,873		
Volume of traffic			0.303			0.385			0.356			0.566			0.592			0.538
Heavy	1.422	0.985-2.051	*0.060*	1.371	0.959-1.959	*0.084*	1.400	0.969-2.023	*0.073*	0.951	0.823-1.099	0.499	0.965	0.833-1.119	0.640	0.959	0.829-1.110	0.576
Moderate	0.974	0.818-1.161	0.773	0.980	0.822-1.167	0.819	0.988	0.828-1.177	0.889	0.945	0.866-1.032	0.206	0.942	0.863-1.029	0.186	0.940	0.861-1.026	0.168
Light	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.
No traffic permitted	1.002	0.761-1.319	0.989	1.004	0.764-1.320	0.975	0.985	0.752-1.292	0.914	0.973	0.863-1.096	0.648	0.984	0.876-1.106	0.790	0.992	0.884-1.113	0.888
Job status (NS-SEC)						<0.001			<0.001						<0.001			<0.001
Not applicable		-		1.000	(ref.)	.	1.000	(ref.)	.		-		1.000	(ref.)	.	1.000	(ref.)	.
Routine and manual		-		1.169	0.849-1.609	0.340	1.144	0.830-1.577	0.410		-		1.037	0.840-1.280	0.736	1.039	0.840-1.285	0.724
Intermediate		-		1.611	1.110-2.337	0.012	1.536	1.061-2.226	0.023		-		0.773	0.623-0.959	0.019	0.779	0.627-0.968	0.024
Higher managerial, admin and professional		-		2.773	1.921-4.004	<0.001	2.565	1.780-3.696	<0.001		-		0.683	0.558-0.836	<0.001	0.695	0.567-0.852	<0.001
Constant	1.961	1.555-2.473	<0.001	1.306	0.874-1.951	0.193	0.268	0.155-0.466	<0.001	0.587	0.497-0.693	<0.001	0.681	0.532-0.872	0.002	0.888	0.652-1.209	0.451
N	13,782			13,782			13,782			9,594			9,594			9,594		

Simplified model results, showing only results for local environmental quality measures and job status. M1 adjusted for exposure to current environment, infant and maternal characteristics. M2 adjusted for exposure to current environment, infant and maternal characteristics and job status. M3 adjusted for exposure to current environment, infant and maternal characteristics, job status and ward-level contextual factors. Each model includes one environmental quality measure only. P-values ≤0.05 shown in bold and p-values between 0.05 and 0.1 shown in bold italic. Hazard ratios represent breastfeeding termination rather than duration. The number of observations (N) varies between models due to differing levels of missing data. Results are weighted to allow for the complex survey design and models are hierarchical to control for the clustering at ward-level. OR=Odds Ratio. HR=Hazard Ratio. CI=Confidence Interval. P-val.=P-value. Env.=Environmental. NS-SEC=National Statistics Socio-economic Classification. If mothers are partnered, highest of mother's and partner's job status is used.

Table A.6: Associations between environmental quality and breastfeeding outcomes (education version)

	Breastfeeding initiation									**Breastfeeding termination**								
		M1			**M2**			**M3**			**M1**			**M2**			**M3**	
	OR	**95% CI**	**P-val.**	**OR**	**95% CI**	**P-val.**	**OR**	**95% CI**	**P-val.**	**HR**	**95% CI**	**P-val.**	**HR**	**95% CI**	**P-val.**	**HR**	**95% CI**	**P-val.**
Subjective Env. Quality	1.125	1.026-1.234	**0.012**	1.040	0.949-1.140	0.405	0.985	0.896-1.083	0.754	0.910	0.864-0.959	**<0.001**	0.940	0.891-0.991	**0.023**	0.952	0.900-1.007	***0.089***
Education (highest qualification)						**<0.001**			**<0.001**						**<0.001**			**<0.001**
None		-		1.000	(ref.)	.	1.000	(ref.)	.		-		1.000	(ref.)	.	1.000	(ref.)	.
Level 1 or 2		-		1.799	1.464-2.210	**<0.001**	1.752	1.428-2.150	**<0.001**		-		0.791	0.687-0.911	**0.001**	0.794	0.689-0.914	**0.001**
Levels 3 to 5 (inc. other and overseas)		-		2.814	2.289-3.459	**<0.001**	2.722	2.214-3.346	**<0.001**		-		0.605	0.518-0.706	**<0.001**	0.607	0.520-0.709	**<0.001**
Level 6 plus		-		5.967	4.573-7.787	**<0.001**	5.626	4.313-7.338	**<0.001**		-		0.524	0.454-0.606	**<0.001**	0.529	0.458-0.611	**<0.001**
Constant	1.079	0.677-1.718	0.749	0.674	0.409-1.112	0.123	0.187	0.099-0.354	**<0.001**	0.894	0.677-1.181	0.429	1.115	0.824-1.508	0.482	1.317	0.945-1.836	0.104
N	13,866			13,857			13,857			9,631			9,625			9,625		
Objective Env. Quality	2.086	1.651-2.634	**<0.001**	1.607	1.277-2.021	**<0.001**	1.460	1.164-1.832	**0.001**	0.783	0.703-0.872	**<0.001**	0.896	0.802-1.002	***0.054***	0.917	0.817-1.028	0.137
Education (highest qualification)						**<0.001**			**<0.001**						**<0.001**			**<0.001**
None		-		1.000	(ref.)	.	1.000	(ref.)	.		-		1.000	(ref.)	.	1.000	(ref.)	.

Level 1 or 2		-		1.721	1.398-2.118	**<0.001**	1.678	1.364-2.064	**<0.001**		-		0.796	0.688-0.922	**0.002**	0.799	0.690-0.924	**0.002**
Levels 3 to 5 (inc. other and overseas)		-		2.654	2.145-3.283	**<0.001**	2.578	2.084-3.190	**<0.001**		-		0.618	0.526-0.726	**<0.001**	0.620	0.528-0.727	**<0.001**
Level 6 plus		-		5.426	4.146-7.101	**<0.001**	5.149	3.935-6.738	**<0.001**		-		0.524	0.450-0.611	**<0.001**	0.529	0.454-0.615	**<0.001**
Constant	0.193	0.087-0.426	**<0.001**	0.202	0.090-0.457	**<0.001**	0.063	0.027-0.150	**<0.001**	1.275	0.900-1.808	0.172	1.189	0.829-1.706	0.347	1.422	0.974-2.135	***0.067***
N	13,752			13,742			13,742			9,573			9,566			9,566		
Support sought since birth																		
No support sought	0.747	0.654-0.854	**<0.001**	0.790	0.692-0.901	**<0.001**	0.793	0.695-0.903	**0.001**	1.050	0.989-1.114	0.110	1.022	0.961-1.087	0.479	1.022	0.961-1.087	0.487
Support sought	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.
Education (highest qualification)						**<0.001**			**<0.001**						**<0.001**			**<0.001**
None		-		1.000	(ref.)	.	1.000	(ref.)	.		-		1.000	(ref.)	.	1.000	(ref.)	.
Level 1 or 2		-		1.820	1.489-2.224	**<0.001**	1.759	1.440-2.149	**<0.001**		-		0.785	0.682-0.903	**0.001**	0.790	0.687-0.908	**0.001**
Levels 3 to 5 (inc. other and overseas)		-		2.894	2.363-3.545	**<0.001**	2.767	2.259-3.390	**<0.001**		-		0.600	0.514-0.699	**<0.001**	0.605	0.519-0.705	**<0.001**
Level 6 plus		-		6.072	4.635-7.956	**<0.001**	5.646	4.312-7.392	**<0.001**		-		0.512	0.443-0.591	**<0.001**	0.520	0.451-0.600	**<0.001**
Constant	2.181	1.729-2.750	**<0.001**	0.919	0.683-1.237	0.577	0.202	0.126-0.324	**<0.001**	0.569	0.483-0.671	**<0.001**	0.838	0.688-1.021	***0.080***	1.065	0.828-1.370	0.624
N	14,185			14,175			14,175			9,881			9,874			9,874		
How often spent time with friends in the last week			**0.005**			**0.032**			**0.039**			**<0.001**			**<0.001**			**<0.001**
Not at all	0.860	0.724-1.020	***0.084***	0.899	0.753-1.074	0.242	0.904	0.758-1.079	0.263	0.982	0.915-1.055	0.622	0.962	0.895-1.034	0.288	0.959	0.893-1.030	0.254
1-2 times	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.

3-6 times	1.073	0.903-1.276	0.422	1.047	0.877-1.250	0.609	1.042	0.873-1.243	0.648	0.826	0.762-0.896	**<0.001**	0.838	0.771-0.910	**<0.001**	0.839	0.773-0.912	**<0.001**
Everyday	0.744	0.603-0.918	**0.006**	0.768	0.620-0.951	**0.015**	0.770	0.622-0.953	**0.016**	0.919	0.807-1.048	0.207	0.928	0.814-1.059	0.269	0.931	0.815-1.062	0.286
Education (highest qualification)						**<0.001**			**<0.001**						**<0.001**			**<0.001**
None		-		1.000	(ref.)	.	1.000	(ref.)	.		-		1.000	(ref.)	.	1.000	(ref.)	.
Level 1 or 2		-		1.797	1.469-2.198	**<0.001**	1.739	1.422-2.128	**<0.001**		-		0.787	0.685-0.905	**0.001**	0.792	0.690-0.909	**0.001**
Levels 3 to 5 (inc. other and overseas)		-		2.876	2.343-3.530	**<0.001**	2.754	2.242-3.383	**<0.001**		-		0.604	0.519-0.704	**<0.001**	0.609	0.523-0.709	**<0.001**
Level 6 plus		-		6.079	4.635-7.973	**<0.001**	5.664	4.319-7.428	**<0.001**		-		0.515	0.447-0.594	**<0.001**	0.522	0.453-0.602	**<0.001**
Constant	2.064	1.612-2.642	**<0.001**	0.887	0.647-1.216	0.458	0.193	0.118-0.314	**<0.001**	0.613	0.520-0.722	**<0.001**	0.890	0.736-1.076	0.230	1.130	0.881-1.451	0.335
N	14,184			14,174			14,174			9,880			9,873			9,873		
Other parents to talk to			0.909			0.925			0.926			**<0.001**			**<0.001**			**<0.001**
Disagree	1.046	0.794-1.377	0.751	1.039	0.781-1.383	0.792	1.039	0.781-1.381	0.794	1.015	0.868-1.185	0.856	1.029	0.880-1.203	0.723	1.026	0.877-1.200	0.751
Neither agree nor disagree	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.
Agree	1.052	0.836-1.323	0.665	0.994	0.788-1.254	0.961	0.994	0.790-1.251	0.959	0.832	0.729-0.948	**0.006**	0.862	0.754-0.984	**0.028**	0.861	0.754-0.983	**0.027**
Education (highest qualification)						**<0.001**			**<0.001**						**<0.001**			**<0.001**
None		-		1.000	(ref.)	.	1.000	(ref.)	.		-		1.000	(ref.)	.	1.000	(ref.)	.
Level 1 or 2		-		1.873	1.525-2.300	**<0.001**	1.811	1.475-2.224	**<0.001**		-		0.764	0.661-0.882	**<0.001**	0.769	0.666-0.888	**<0.001**
Levels 3 to 5 (inc. other and overseas)		-		2.998	2.435-3.691	**<0.001**	2.869	2.329-3.533	**<0.001**		-		0.585	0.499-0.687	**<0.001**	0.590	0.503-0.693	**<0.001**
Level 6 plus		-		6.417	4.882-8.433	**<0.001**	5.966	4.542-7.838	**<0.001**		-		0.502	0.434-0.581	**<0.001**	0.510	0.441-0.591	**<0.001**
Constant	1.858	1.354-2.549	**<0.001**	0.807	0.559-1.165	0.252	0.169	0.101-0.285	**<0.001**	0.662	0.533-0.822	**<0.001**	0.963	0.752-1.234	0.765	1.218	0.906-1.626	0.191

N	13,476			13,467			13,467			9,391			9,385			9,385		
Feelings about neighbour friendliness			0.175			0.316			0.330			**0.012**			***0.073***			***0.089***
NA / Don't know / Can't say	0.693	0.492-0.977	**0.036**	0.755	0.533-1.068	0.113	0.766	0.543-1.082	0.131	1.146	0.920-1.427	0.224	1.052	0.844-1.311	0.654	1.045	0.841-1.300	0.690
Unfriendly	0.769	0.511-1.157	0.208	0.777	0.515-1.172	0.229	0.780	0.517-1.176	0.236	0.902	0.693-1.174	0.443	0.889	0.680-1.162	0.389	0.890	0.681-1.164	0.395
Neither friendly nor unfriendly	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.
Friendly	0.901	0.754-1.077	0.254	0.887	0.743-1.059	0.184	0.880	0.738-1.051	0.158	0.901	0.815-0.996	**0.042**	0.901	0.812-1.000	***0.050***	0.903	0.813-1.002	***0.054***
Education (highest qualification)						**<0.001**			**<0.001**						**<0.001**			**<0.001**
None		-		1.000	(ref.)	.	1.000	(ref.)	.		-		1.000	(ref.)	.	1.000	(ref.)	.
Level 1 or 2		-		1.817	1.484-2.225	**<0.001**	1.759	1.437-2.152	**<0.001**		-		0.792	0.688-0.913	**0.001**	0.797	0.693-0.917	**0.002**
Levels 3 to 5 (inc. other and overseas)		-		2.916	2.379-3.574	**<0.001**	2.792	2.277-3.423	**<0.001**		-		0.604	0.518-0.705	**<0.001**	0.609	0.522-0.710	**<0.001**
Level 6 plus		-		6.166	4.696-8.095	**<0.001**	5.739	4.373-7.532	**<0.001**		-		0.517	0.448-0.596	**<0.001**	0.524	0.455-0.604	**<0.001**
Constant	2.150	1.642-2.815	**<0.001**	0.930	0.668-1.293	0.665	0.204	0.124-0.337	**<0.001**	0.625	0.515-0.758	**<0.001**	0.909	0.728-1.135	0.401	1.152	0.882-1.505	0.300
N	14,187			14,177			14,177			9,883			9,876			9,876		
Central heating in house																		
No central heating	0.752	0.600-0.942	**0.013**	0.833	0.672-1.033	***0.095***	0.852	0.687-1.055	0.141	0.908	0.797-1.036	0.152	0.877	0.768-1.001	***0.051***	0.872	0.765-0.994	**0.041**
Central heating	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.
Education (highest qualification)						**<0.001**			**<0.001**						**<0.001**			**<0.001**
None		-		1.000	(ref.)	.	1.000	(ref.)	.		-		1.000	(ref.)	.	1.000	(ref.)	.

Level 1 or 2		-		1.814	1.488-2.210	**<0.001**	1.756	1.441-2.140	**<0.001**		-		0.780	0.677-0.898	**0.001**	0.785	0.682-0.903	**0.001**
Levels 3 to 5 (inc. other and overseas)		-		2.909	2.376-3.560	**<0.001**	2.786	2.275-3.412	**<0.001**		-		0.596	0.511-0.695	**<0.001**	0.601	0.516-0.701	**<0.001**
Level 6 plus		-		6.114	4.675-7.996	**<0.001**	5.699	4.359-7.451	**<0.001**		-		0.506	0.438-0.584	**<0.001**	0.514	0.446-0.593	**<0.001**
Constant	2.030	1.617-2.548	**<0.001**	0.859	0.646-1.142	0.296	0.187	0.117-0.300	**<0.001**	0.586	0.498-0.689	**<0.001**	0.865	0.714-1.049	0.141	1.100	0.856-1.415	0.456
N	14,186			14,176			14,176			9,882			9,875			9,875		
Poor public transport			0.100			0.231			0.500			0.197			0.309			0.344
Very common	1.120	0.881-1.424	0.355	1.104	0.874-1.394	0.408	1.028	0.813-1.300	0.819	0.885	0.781-1.003	***0.056***	0.900	0.794-1.021	0.102	0.909	0.800-1.033	0.144
Fairly common	1.246	1.005-1.546	**0.045**	1.198	0.964-1.489	0.104	1.154	0.926-1.438	0.202	0.996	0.909-1.092	0.939	1.000	0.913-1.094	0.995	1.007	0.920-1.103	0.877
Not very common	0.987	0.844-1.155	0.875	0.993	0.844-1.168	0.932	0.982	0.834-1.156	0.830	0.992	0.911-1.080	0.854	0.993	0.912-1.081	0.866	0.998	0.916-1.088	0.964
Not at all common	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.
Education (highest qualification)						**<0.001**			**<0.001**						**<0.001**			**<0.001**
None		-		1.000	(ref.)	.	1.000	(ref.)	.		-		1.000	(ref.)	.	1.000	(ref.)	.
Level 1 or 2		-		1.803	1.464-2.221	**<0.001**	1.743	1.416-2.146	**<0.001**		-		0.756	0.655-0.873	**<0.001**	0.761	0.660-0.878	**<0.001**
Levels 3 to 5 (inc. other and overseas)		-		2.789	2.261-3.439	**<0.001**	2.663	2.157-3.288	**<0.001**		-		0.552	0.466-0.654	**<0.001**	0.557	0.471-0.659	**<0.001**
Level 6 plus		-		6.521	4.900-8.679	**<0.001**	6.055	4.547-8.064	**<0.001**		-		0.467	0.399-0.548	**<0.001**	0.475	0.405-0.556	**<0.001**
Constant	1.860	1.438-2.407	**<0.001**	0.809	0.595-1.101	0.178	0.189	0.108-0.331	**<0.001**	0.611	0.510-0.731	**<0.001**	0.940	0.756-1.169	0.579	1.193	0.913-1.558	0.195
N	12,673			12,665			12,665			8,742			8,736			8,736		
Food shops and supermarkets that are easy to get to			0.230			0.301			0.184			0.246			0.212			0.301

Not at all common	0.931	0.720-1.203	0.583	0.947	0.732-1.226	0.682	0.909	0.702-1.178	0.472	0.872	0.753-1.011	***0.069***	0.867	0.746-1.008	***0.064***	0.880	0.758-1.022	***0.093***
Not very common	0.840	0.692-1.020	***0.078***	0.864	0.710-1.052	0.146	0.839	0.689-1.022	***0.082***	0.965	0.838-1.111	0.617	0.956	0.829-1.102	0.532	0.963	0.834-1.112	0.609
Fairly common	0.894	0.778-1.028	0.116	0.892	0.777-1.025	0.108	0.880	0.766-1.011	***0.072***	0.969	0.908-1.034	0.342	0.962	0.899-1.029	0.257	0.964	0.901-1.031	0.286
Very common	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.
Education (highest qualification)						**<0.001**			**<0.001**						**<0.001**			**<0.001**
None		-		1.000	(ref.)	.	1.000	(ref.)	.		-		1.000	(ref.)	.	1.000	(ref.)	.
Level 1 or 2		-		1.825	1.494-2.230	**<0.001**	1.763	1.445-2.152	**<0.001**		-		0.783	0.681-0.900	**0.001**	0.788	0.686-0.905	**0.001**
Levels 3 to 5 (inc. other and overseas)		-		2.934	2.394-3.597	**<0.001**	2.806	2.288-3.440	**<0.001**		-		0.599	0.514-0.697	**<0.001**	0.603	0.518-0.703	**<0.001**
Level 6 plus		-		6.182	4.723-8.093	**<0.001**	5.743	4.391-7.510	**<0.001**		-		0.509	0.442-0.587	**<0.001**	0.517	0.449-0.596	**<0.001**
Constant	2.069	1.655-2.587	**<0.001**	0.878	0.657-1.173	0.378	0.191	0.120-0.305	**<0.001**	0.595	0.505-0.701	**<0.001**	0.874	0.718-1.063	0.178	1.101	0.860-1.411	0.444
N	14,177			14,167			14,167			9,873			9,866			9,866		
Volume of traffic			0.303			0.386			0.383			0.566			0.565			0.530
Heavy	1.422	0.985-2.051	***0.060***	1.372	0.944-1.994	***0.097***	1.394	0.950-2.045	***0.090***	0.951	0.823-1.099	0.499	0.944	0.811-1.098	0.452	0.939	0.809-1.090	0.409
Moderate	0.974	0.818-1.161	0.773	0.965	0.811-1.147	0.684	0.971	0.816-1.156	0.744	0.945	0.866-1.032	0.206	0.945	0.864-1.034	0.221	0.943	0.862-1.032	0.205
Light	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.
No traffic permitted	1.002	0.761-1.319	0.989	1.027	0.781-1.350	0.851	1.008	0.768-1.322	0.955	0.973	0.863-1.096	0.648	0.969	0.858-1.094	0.613	0.976	0.865-1.101	0.694
Education (highest qualification)						**<0.001**			**<0.001**						**<0.001**			**<0.001**
None		-		1.000	(ref.)	.	1.000	(ref.)	.		-		1.000	(ref.)	.	1.000	(ref.)	.
Level 1 or 2		-		1.811	1.465-2.237	**<0.001**	1.747	1.416-2.156	**<0.001**		-		0.785	0.678-0.908	**0.001**	0.790	0.684-0.913	**0.001**
Levels 3 to 5 (inc. other and overseas)		-		2.865	2.317-3.541	**<0.001**	2.733	2.212-3.376	**<0.001**		-		0.603	0.515-0.707	**<0.001**	0.608	0.520-0.712	**<0.001**

	OR	M1 95% CI	P-val.	OR	M2 95% CI	P-val.	OR	M3 95% CI	P-val.	HR	M1 95% CI	P-val.	HR	M2 95% CI	P-val.	HR	M3 95% CI	P-val.
Level 6 plus		-		6.017	4.576-7.912	**<0.001**	5.579	4.247-7.328	**<0.001**		-		0.510	0.439-0.591	**<0.001**	0.517	0.446-0.600	**<0.001**
Constant	1.961	1.555-2.473	**<0.001**	0.849	0.632-1.140	0.277	0.182	0.115-0.289	**<0.001**	0.587	0.497-0.693	**<0.001**	0.858	0.703-1.048	0.133	1.143	0.878-1.488	0.320
N	13,782			13,772			13,772			9,594			9,587			9,587		

Simplified model results, showing only results for local environmental quality measures and education. M1 adjusted for exposure to current environment, infant and maternal characteristics. M2 adjusted for exposure to current environment, infant and maternal characteristics and education. M3 adjusted for exposure to current environment, infant and maternal characteristics, job status and ward-level contextual factors. Each model includes one environmental quality measure only. P-values ≤0.05 shown in bold and p-values between 0.05 and 0.1 shown in bold italic. Hazard ratios represent breastfeeding termination rather than duration. The number of observations (N) varies between models due to differing levels of missing data. Results are weighted to allow for the complex survey design and models are hierarchical to control for the clustering at ward-level. OR=Odds Ratio. HR=Hazard Ratio. CI=Confidence Interval. P-val.=P-value. Env.=Environmental. Education is measured by highest qualification level. If mothers are partnered, highest of mother's and partner's qualifications used.

Table A.7: Associations between environmental quality and breastfeeding outcomes (all SES version)

	Breastfeeding initiation									Breastfeeding termination								
		M1			M2			M3			M1			M2			M3	
	OR	**95% CI**	**P-val.**	**OR**	**95% CI**	**P-val.**	**OR**	**95% CI**	**P-val.**	**HR**	**95% CI**	**P-val.**	**HR**	**95% CI**	**P-val.**	**HR**	**95% CI**	**P-val.**
Subjective Env. Quality	1.125	1.026-1.234	**0.012**	0.968	0.885-1.059	0.477	0.925	0.844-1.014	***0.097***	0.910	0.864-0.959	**<0.001**	0.958	0.907-1.012	0.124	0.969	0.915-1.025	0.273
Income (OECD equivalised quintiles)						**0.016**			**0.042**						0.770			0.663
Lowest		-		1.000	(ref.)	.	1.000	(ref.)	.		-		1.000	(ref.)	.	1.000	(ref.)	.
Second lowest		-		1.026	0.822-1.282	0.820	1.008	0.808-1.257	0.946		-		0.971	0.848-1.112	0.673	0.972	0.850-1.112	0.678
Middle		-		1.249	0.976-1.599	***0.078***	1.204	0.942-1.538	0.138		-		0.968	0.842-1.113	0.646	0.972	0.846-1.116	0.684
Second highest		-		1.493	1.148-1.940	**0.003**	1.428	1.099-1.856	**0.008**		-		0.999	0.873-1.144	0.989	1.007	0.880-1.152	0.917
Highest		-		1.507	1.078-2.105	**0.016**	1.410	1.008-1.974	**0.045**		-		1.025	0.897-1.172	0.714	1.039	0.908-1.188	0.583
Job status (NS-SEC)						**0.002**			**0.004**						**<0.001**			**<0.001**
Not applicable		-		1.000	(ref.)	.	1.000	(ref.)	.		-		1.000	(ref.)	.	1.000	(ref.)	.
Routine and manual		-		1.134	0.843-1.525	0.405	1.122	0.833-1.511	0.448		-		1.075	0.862-1.340	0.522	1.074	0.859-1.343	0.530
Intermediate		-		1.369	0.983-1.906	***0.063***	1.346	0.967-1.874	***0.078***		-		0.842	0.670-1.058	0.140	0.841	0.668-1.059	0.141

Higher managerial, admin and professional		-		1.598	1.132-2.256	**0.008**	1.551	1.100-2.187	**0.012**		-		0.833	0.674-1.028	***0.088***	0.836	0.676-1.033	***0.098***
Education (highest qualification)						**<0.001**			**<0.001**						**<0.001**			**<0.001**
None		-		1.000	(ref.)	.	1.000	(ref.)	.		-		1.000	(ref.)	.	1.000	(ref.)	.
Level 1 or 2		-		1.617	1.317-1.986	**<0.001**	1.592	1.297-1.954	**<0.001**		-		0.815	0.712-0.933	**0.003**	0.816	0.713-0.933	**0.003**
Levels 3 to 5 (inc. other and overseas)		-		2.351	1.883-2.934	**<0.001**	2.313	1.850-2.891	**<0.001**		-		0.636	0.544-0.743	**<0.001**	0.636	0.545-0.743	**<0.001**
Level 6 plus		-		4.421	3.295-5.930	**<0.001**	4.294	3.196-5.769	**<0.001**		-		0.561	0.483-0.652	**<0.001**	0.563	0.485-0.654	**<0.001**
Constant	1.079	0.677-1.718	0.749	0.767	0.446-1.317	0.336	0.238	0.120-0.472	**<0.001**	0.894	0.677-1.181	0.429	1.047	0.726-1.511	0.805	1.215	0.816-1.811	0.338
N	13,866			13,843			13,843			9,631			9,614			9,614		
Objective Env. Quality	2.086	1.651-2.634	**<0.001**	1.396	1.121-1.739	**0.003**	1.296	1.042-1.612	**0.020**	0.783	0.703-0.872	**<0.001**	0.947	0.844-1.062	0.351	0.963	0.856-1.083	0.525
Income (OECD equivalised quintiles)						0.177			0.276						0.967			0.922
Lowest		-		1.000	(ref.)	.	1.000	(ref.)	.		-		1.000	(ref.)	.	1.000	(ref.)	.
Second lowest		-		0.975	0.784-1.213	0.823	0.961	0.774-1.193	0.718		-		0.996	0.868-1.143	0.955	0.996	0.869-1.141	0.952
Middle		-		1.155	0.904-1.475	0.250	1.117	0.876-1.423	0.373		-		0.984	0.854-1.133	0.820	0.987	0.859-1.136	0.860
Second highest		-		1.327	1.011-1.742	**0.042**	1.273	0.971-1.669	***0.080***		-		1.002	0.871-1.153	0.976	1.010	0.879-1.161	0.886
Highest		-		1.288	0.912-1.820	0.151	1.207	0.855-1.705	0.285		-		1.018	0.888-1.166	0.801	1.031	0.899-1.183	0.660
Job status (NS-SEC)						**0.009**			**0.016**						**<0.001**			**<0.001**
Not applicable		-		1.000	(ref.)	.	1.000	(ref.)	.		-		1.000	(ref.)	.	1.000	(ref.)	.
Routine and manual		-		1.064	0.779-1.454	0.697	1.056	0.772-1.443	0.735		-		1.045	0.842-1.297	0.692	1.046	0.841-1.300	0.688
Intermediate		-		1.201	0.835-1.728	0.323	1.182	0.822-1.699	0.366		-		0.817	0.652-1.024	***0.080***	0.819	0.653-1.028	***0.085***
Higher managerial,		-		1.479	1.020-2.144	**0.039**	1.440	0.994-2.085	***0.054***		-		0.805	0.655-0.990	**0.040**	0.810	0.658-0.997	**0.047**

admin and professional																		
Education (highest qualification)						**<0.001**			**<0.001**						**<0.001**			**<0.001**
None		-		1.000	(ref.)	.	1.000	(ref.)	.		-		1.000	(ref.)	.	1.000	(ref.)	.
Level 1 or 2		-		1.607	1.308-1.975	**<0.001**	1.582	1.287-1.944	**<0.001**		-		0.818	0.711-0.941	**0.005**	0.818	0.712-0.940	**0.005**
Levels 3 to 5 (inc. other and overseas)		-		2.341	1.865-2.938	**<0.001**	2.309	1.837-2.901	**<0.001**		-		0.648	0.553-0.760	**<0.001**	0.647	0.553-0.758	**<0.001**
Level 6 plus		-		4.293	3.173-5.808	**<0.001**	4.184	3.089-5.668	**<0.001**		-		0.563	0.482-0.657	**<0.001**	0.563	0.483-0.657	**<0.001**
Constant	0.193	0.087-0.426	**<0.001**	0.280	0.120-0.652	**0.003**	0.091	0.037-0.225	**<0.001**	1.275	0.900-1.808	0.172	1.046	0.694-1.577	0.829	1.253	0.802-1.956	0.322
N	13,752			13,727			13,727			9,573			9,554			9,554		
Support sought since birth																		
No support sought	0.747	0.654-0.854	**<0.001**	0.787	0.690-0.898	**<0.001**	0.790	0.693-0.900	**<0.001**	1.050	0.989-1.114	0.110	1.016	0.958-1.079	0.592	1.016	0.958-1.079	0.592
Support sought	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.
Income (OECD equivalised quintiles)						**0.018**			***0.058***						0.832			0.732
Lowest		-		1.000	(ref.)	.	1.000	(ref.)	.		-		1.000	(ref.)	.	1.000	(ref.)	.
Second lowest		-		1.029	0.825-1.282	0.803	1.007	0.809-1.253	0.952		-		0.971	0.848-1.111	0.665	0.973	0.851-1.112	0.687
Middle		-		1.258	0.982-1.612	***0.070***	1.201	0.940-1.536	0.143		-		0.956	0.833-1.097	0.522	0.963	0.840-1.104	0.589
Second highest		-		1.498	1.156-1.941	**0.002**	1.414	1.092-1.832	**0.009**		-		0.981	0.858-1.123	0.785	0.994	0.869-1.136	0.927
Highest		-		1.490	1.057-2.100	**0.023**	1.374	0.974-1.938	***0.071***		-		1.008	0.883-1.150	0.910	1.026	0.898-1.172	0.707
Job status (NS-SEC)						**0.001**			**0.004**						**<0.001**			**<0.001**
Not applicable		-		1.000	(ref.)	.	1.000	(ref.)	.		-		1.000	(ref.)	.	1.000	(ref.)	.
Routine and manual		-		1.105	0.833-1.467	0.489	1.093	0.823-1.452	0.537		-		1.072	0.865-1.329	0.525	1.074	0.865-1.334	0.518
Intermediate		-		1.312	0.946-1.820	0.103	1.282	0.926-1.777	0.135		-		0.837	0.668-1.050	0.124	0.840	0.669-1.055	0.134

Higher managerial, admin and professional		-		1.580	1.128-2.214	**0.008**	1.524	1.089-2.131	**0.014**		-		0.830	0.676-1.020	***0.077***	0.837	0.680-1.029	***0.092***
Education (highest qualification)						**<0.001**			**<0.001**						**<0.001**			**<0.001**
None		-		1.000	(ref.)	.	1.000	(ref.)	.		-		1.000	(ref.)	.	1.000	(ref.)	.
Level 1 or 2		-		1.626	1.330-1.988	**<0.001**	1.596	1.305-1.953	**<0.001**		-		0.812	0.710-0.928	**0.002**	0.814	0.713-0.929	**0.002**
Levels 3 to 5 (inc. other and overseas)		-		2.386	1.917-2.970	**<0.001**	2.340	1.877-2.917	**<0.001**		-		0.635	0.544-0.740	**<0.001**	0.636	0.546-0.741	**<0.001**
Level 6 plus		-		4.404	3.262-5.946	**<0.001**	4.268	3.157-5.770	**<0.001**		-		0.553	0.476-0.641	**<0.001**	0.556	0.480-0.644	**<0.001**
Constant	2.181	1.729-2.750	**<0.001**	0.781	0.522-1.170	**0.231**	0.204	0.177-0.355	**<0.001**	0.569	0.483-0.671	**<0.001**	0.863	0.663-1.123	0.274	1.054	0.776-1.430	0.738
N	14,185			14,160			14,160			9,881			9,862			9,862		
How often spent time with friends in the last week			**0.005**			***0.093***			***0.093***			**<0.001**			**<0.001**			**<0.001**
Not at all	0.860	0.724-1.020	***0.084***	0.926	0.778-1.103	0.388	0.927	0.780-1.102	0.391	0.982	0.915-1.055	0.622	0.961	0.895-1.031	0.269	0.960	0.895-1.030	0.252
1-2 times	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.
3-6 times	1.073	0.903-1.276	0.422	1.048	0.878-1.252	0.603	1.043	0.874-1.245	0.641	0.826	0.762-0.896	**<0.001**	0.839	0.772-0.911	**<0.001**	0.840	0.773-0.912	**<0.001**
Everyday	0.744	0.603-0.918	**0.006**	0.795	0.638-0.992	**0.042**	0.792	0.635-0.987	**0.038**	0.919	0.807-1.048	0.207	0.918	0.804-1.048	0.206	0.921	0.806-1.052	0.225
Income (OECD equivalised quintiles)						**0.026**			***0.076***						0.821			0.725
Lowest	1.000	(ref.)	.	1.000	(ref.)	.		-		1.000	(ref.)	.	1.000	(ref.)	.			
Second lowest	1.023	0.822-1.272	0.841	1.001	0.806-1.242	0.995		-		0.977	0.852-1.119	0.735	0.979	0.856-1.120	0.761			
Middle	1.241	0.971-1.587	***0.085***	1.186	0.929-1.513	0.170		-		0.957	0.834-1.099	0.536	0.965	0.842-1.106	0.607			
Second highest	1.474	1.139-1.908	**0.003**	1.392	1.076-1.802	**0.012**		-		0.984	0.858-1.127	0.813	0.996	0.870-1.141	0.956			
Highest	1.452	1.026-2.054	**0.035**	1.339	0.946-1.896	0.100		-		1.012	0.886-1.156	0.858	1.031	0.901-1.178	0.660			

Job status (NS-SEC)						**0.002**			**0.004**						**<0.001**			**<0.001**
Not applicable	1.000	(ref.)	.	1.000	(ref.)	.		-		1.000	(ref.)	.	1.000	(ref.)	.			
Routine and manual	1.093	0.819-1.460	0.545	1.083	0.810-1.448	0.590		-		1.080	0.871-1.338	0.486	1.082	0.871-1.344	0.479			
Intermediate	1.297	0.932-1.804	0.123	1.268	0.912-1.763	0.158		-		0.843	0.672-1.059	0.143	0.847	0.673-1.065	0.154			
Higher managerial, admin and professional	1.561	1.110-2.193	**0.010**	1.506	1.073-2.112	**0.018**		-		0.837	0.681-1.030	***0.093***	0.844	0.685-1.040	0.111			
Education (highest qualification)						**<0.001**			**<0.001**						**<0.001**			**<0.001**
None		-		1.000	(ref.)	.	1.000	(ref.)	.		-		1.000	(ref.)	.	1.000	(ref.)	.
Level 1 or 2		-		1.617	1.321-1.981	**<0.001**	1.589	1.297-1.947	**<0.001**		-		0.813	0.712-0.929	**0.002**	0.815	0.714-0.930	**0.002**
Levels 3 to 5 (inc. other and overseas)		-		2.392	1.917-2.986	**<0.001**	2.348	1.879-2.936	**<0.001**		-		0.639	0.548-0.744	**<0.001**	0.640	0.550-0.744	**<0.001**
Level 6 plus		-		4.467	3.302-6.044	**<0.001**	4.333	3.198-5.870	**<0.001**		-		0.556	0.479-0.644	**<0.001**	0.558	0.482-0.646	**<0.001**
Constant	2.064	1.612-2.642	**<0.001**	0.753	0.497-1.139	0.178	0.193	0.110-0.339	**<0.001**	0.613	0.520-0.722	**<0.001**	0.908	0.701-1.177	0.467	1.107	0.818-1.500	0.510
N	14,184			14,159			14,159			9,880			9,861			9,861		
Other parents to talk to			0.909			0.719			0.750			**<0.001**			**<0.001**			**<0.001**
Disagree	1.046	0.794-1.377	0.751	1.072	0.804-1.428	0.636	1.067	0.801-1.420	0.659	1.015	0.868-1.185	0.856	1.023	0.874-1.197	0.775	1.020	0.872-1.193	0.806
Neither agree nor disagree	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.
Agree	1.052	0.836-1.323	0.665	0.978	0.773-1.239	0.856	0.979	0.775-1.238	0.862	0.832	0.729-0.948	**0.006**	0.863	0.755-0.987	**0.032**	0.861	0.754-0.984	**0.028**
Income (OECD equivalised quintiles)						**0.017**			***0.057***						0.743			0.635
Lowest		-		1.000	(ref.)	.	1.000	(ref.)	.		-		1.000	(ref.)	.	1.000	(ref.)	.
Second lowest		-		1.092	0.873-1.366	0.441	1.067	0.855-1.332	0.567		-		0.951	0.823-1.099	0.494	0.955	0.828-1.102	0.532
Middle		-		1.323	1.033-1.696	**0.027**	1.264	0.989-1.615	***0.061***		-		0.944	0.814-1.095	0.446	0.953	0.823-1.105	0.527

Second highest		-		1.552	1.191-2.022	**0.001**	1.463	1.124-1.905	**0.005**		-		0.969	0.838-1.121	0.676	0.984	0.851-1.137	0.825
Highest		-		1.575	1.115-2.224	**0.010**	1.449	1.025-2.046	**0.035**		-		1.001	0.869-1.154	0.987	1.022	0.885-1.179	0.769
Job status (NS-SEC)						**0.004**			**0.011**						**<0.001**			**<0.001**
Not applicable		-		1.000	(ref.)	.	1.000	(ref.)	.		-		1.000	(ref.)	.	1.000	(ref.)	.
Routine and manual		-		1.044	0.766-1.422	0.785	1.033	0.758-1.409	0.836		-		1.172	0.921-1.490	0.196	1.177	0.924-1.500	0.187
Intermediate		-		1.205	0.851-1.706	0.293	1.175	0.830-1.662	0.363		-		0.915	0.713-1.175	0.487	0.921	0.717-1.184	0.522
Higher managerial, admin and professional		-		1.491	1.042-2.134	**0.029**	1.433	1.003-2.047	**0.048**		-		0.903	0.719-1.135	0.382	0.913	0.726-1.148	0.437
Education (highest qualification)						**<0.001**			**<0.001**						**<0.001**			**<0.001**
None		-		1.000	(ref.)	.	1.000	(ref.)	.		-		1.000	(ref.)	.	1.000	(ref.)	.
Level 1 or 2		-		1.685	1.372-2.069	**<0.001**	1.655	1.347-2.034	**<0.001**		-		0.787	0.687-0.902	**0.001**	0.789	0.690-0.903	**0.001**
Levels 3 to 5 (inc. other and overseas)		-		2.485	1.991-3.101	**<0.001**	2.441	1.953-3.051	**<0.001**		-		0.618	0.528-0.724	**<0.001**	0.619	0.529-0.725	**<0.001**
Level 6 plus		-		4.659	3.452-6.286	**<0.001**	4.521	3.347-6.107	**<0.001**		-		0.541	0.465-0.628	**<0.001**	0.544	0.468-0.631	**<0.001**
Constant	1.858	1.354-2.549	**<0.001**	0.714	0.459-1.113	0.137	0.178	0.098-0.322	**<0.001**	0.662	0.533-0.822	**<0.001**	0.918	0.657-1.282	0.615	1.118	0.772-1.620	0.555
N	13,476			13,456			13,456			9,391			9,377			9,377		
Feelings about neighbour friendliness			0.175			0.276			0.275			**0.012**			0.116			0.122
NA / Don't know / Can't say	0.693	0.492-0.977	**0.036**	0.768	0.542-1.089	0.139	0.776	0.549-1.098	0.152	1.146	0.920-1.427	0.224	1.057	0.848-1.317	0.624	1.053	0.847-1.308	0.644
Unfriendly	0.769	0.511-1.157	0.208	0.809	0.539-1.214	0.306	0.806	0.536-1.212	0.300	0.902	0.693-1.174	0.443	0.879	0.671-1.150	0.346	0.881	0.673-1.152	0.354
Neither friendly nor unfriendly	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.
Friendly	0.901	0.754-1.077	0.254	0.853	0.710-1.025	***0.089***	0.850	0.707-1.020	***0.081***	0.901	0.815-0.996	**0.042**	0.913	0.823-1.014	***0.088***	0.914	0.823-1.014	***0.089***

Income (OECD equivalised quintiles)						**0.020**			***0.060***						0.786			0.670
Lowest		-		1.000	(ref.)	.	1.000	(ref.)	.		-		1.000	(ref.)	.	1.000	(ref.)	.
Second lowest		-		1.031	0.828-1.283	0.785	1.009	0.812-1.254	0.936		-		0.968	0.845-1.108	0.632	0.970	0.849-1.108	0.649
Middle		-		1.259	0.983-1.613	***0.068***	1.203	0.941-1.537	0.141		-		0.956	0.832-1.097	0.520	0.962	0.839-1.103	0.582
Second highest		-		1.505	1.159-1.954	**0.002**	1.421	1.095-1.845	**0.008**		-		0.985	0.860-1.128	0.827	0.997	0.871-1.141	0.964
Highest		-		1.484	1.049-2.098	**0.026**	1.368	0.967-1.936	***0.077***		-		1.012	0.887-1.155	0.856	1.030	0.902-1.177	0.662
Job status (NS-SEC)						**0.001**			**0.003**						**<0.001**			**<0.001**
Not applicable		-		1.000	(ref.)	.	1.000	(ref.)	.		-		1.000	(ref.)	.	1.000	(ref.)	.
Routine and manual		-		1.083	0.814-1.441	0.583	1.073	0.806-1.428	0.631		-		1.073	0.866-1.329	0.520	1.074	0.865-1.334	0.516
Intermediate		-		1.292	0.934-1.788	0.122	1.264	0.914-1.748	0.157		-		0.839	0.669-1.052	0.129	0.841	0.670-1.057	0.138
Higher managerial, admin and professional		-		1.558	1.113-2.181	**0.010**	1.503	1.076-2.101	**0.017**		-		0.834	0.679-1.026	***0.086***	0.840	0.683-1.034	0.101
Education (highest qualification)						**<0.001**			**<0.001**						**<0.001**			**<0.001**
None		-		1.000	(ref.)	.	1.000	(ref.)	.		-		1.000	(ref.)	.	1.000	(ref.)	.
Level 1 or 2		-		1.631	1.332-1.996	**<0.001**	1.602	1.308-1.962	**<0.001**		-		0.818	0.715-0.937	**0.004**	0.820	0.717-0.937	**0.004**
Levels 3 to 5 (inc. other and overseas)		-		2.412	1.936-3.006	**<0.001**	2.367	1.897-2.954	**<0.001**		-		0.638	0.546-0.745	**<0.001**	0.639	0.548-0.745	**<0.001**
Level 6 plus		-		4.489	3.320-6.070	**<0.001**	4.351	3.213-5.891	**<0.001**		-		0.556	0.479-0.645	**<0.001**	0.558	0.481-0.647	**<0.001**
Constant	2.150	1.642-2.815	**<0.001**	0.822	0.544-1.241	0.351	0.213	0.121-0.378	**<0.001**	0.625	0.515-0.758	**<0.001**	0.925	0.698-1.226	0.588	1.132	0.824-1.554	0.444
N	14,187			14,162			14,162			9,883			9,864			9,864		
Central heating in house																		
No central heating	0.752	0.600-0.942	**0.013**	0.898	0.723-1.116	0.332	0.907	0.731-1.126	0.377	0.908	0.797-1.036	0.152	0.863	0.757-0.984	**0.027**	0.862	0.757-0.981	**0.024**

Central heating	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.
Income (OECD equivalised quintiles)						**0.025**			***0.074***						0.855			0.779
Lowest		-		1.000	(ref.)	.	1.000	(ref.)	.		-		1.000	(ref.)	.	1.000	(ref.)	.
Second lowest		-		1.034	0.831-1.286	0.764	1.012	0.815-1.256	0.916		-		0.966	0.843-1.106	0.614	0.968	0.847-1.107	0.633
Middle		-		1.258	0.984-1.609	***0.067***	1.202	0.942-1.534	0.139		-		0.946	0.823-1.086	0.431	0.953	0.831-1.093	0.490
Second highest		-		1.491	1.149-1.933	**0.003**	1.408	1.086-1.826	**0.010**		-		0.965	0.844-1.104	0.608	0.978	0.855-1.117	0.739
Highest		-		1.472	1.046-2.073	**0.027**	1.358	0.964-1.914	***0.080***		-		0.991	0.868-1.131	0.893	1.009	0.884-1.152	0.894
Job status (NS-SEC)						**0.002**			**0.005**						**<0.001**			**<0.001**
Not applicable		-		1.000	(ref.)	.	1.000	(ref.)	.		-		1.000	(ref.)	.	1.000	(ref.)	.
Routine and manual		-		1.096	0.824-1.458	0.529	1.084	0.814-1.443	0.580		-		1.080	0.871-1.339	0.484	1.082	0.871-1.344	0.479
Intermediate		-		1.302	0.939-1.805	0.113	1.272	0.918-1.763	0.148		-		0.844	0.673-1.057	0.139	0.847	0.675-1.062	0.151
Higher managerial, admin and professional		-		1.563	1.114-2.193	**0.010**	1.507	1.076-2.112	**0.017**		-		0.833	0.679-1.023	***0.082***	0.840	0.683-1.033	***0.098***
Education (highest qualification)						**<0.001**			**<0.001**						**<0.001**			**<0.001**
None		-		1.000	(ref.)	.	1.000	(ref.)	.		-		1.000	(ref.)	.	1.000	(ref.)	.
Level 1 or 2		-		1.629	1.335-1.988	**<0.001**	1.601	1.311-1.954	**<0.001**		-		0.808	0.706-0.924	**0.002**	0.810	0.709-0.925	**0.002**
Levels 3 to 5 (inc. other and overseas)		-		2.413	1.939-3.004	**<0.001**	2.368	1.900-2.952	**<0.001**		-		0.634	0.544-0.738	**<0.001**	0.635	0.545-0.739	**<0.001**
Level 6 plus		-		4.490	3.326-6.061	**<0.001**	4.354	3.221-5.886	**<0.001**		-		0.550	0.474-0.638	**<0.001**	0.553	0.477-0.640	**<0.001**
Constant	2.030	1.617-2.548	**<0.001**	0.724	0.488-1.074	0.108	0.186	0.107-0.324	**<0.001**	0.586	0.498-0.689	**<0.001**	0.888	0.684-1.152	0.371	1.078	0.795-1.463	0.628
N	14,186			14,161			14,161			9,882			9,863			9,863		
Poor public transport			0.100			0.170			0.427			0.197			0.309			0.349
Very common	1.120	0.881-1.424	0.355	1.127	0.891-1.425	0.319	1.043	0.823-1.322	0.725	0.885	0.781-1.003	***0.056***	0.901	0.795-1.021	0.102	0.910	0.802-1.033	0.146

Fairly common	1.246	1.005-1.546	**0.045**	1.233	0.987-1.542	***0.065***	1.182	0.943-1.482	0.146	0.996	0.909-1.092	0.939	0.999	0.911-1.096	0.982	1.007	0.917-1.105	0.887
Not very common	0.987	0.844-1.155	0.875	1.006	0.855-1.184	0.940	0.993	0.843-1.168	0.929	0.992	0.911-1.080	0.854	0.991	0.908-1.082	0.839	0.997	0.912-1.089	0.940
Not at all common	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.
Income (OECD equivalised quintiles)						**0.006**			**0.030**						0.924			0.874
Lowest		-		1.000	(ref.)	.	1.000	(ref.)	.		-		1.000	(ref.)	.	1.000	(ref.)	.
Second lowest		-		1.083	0.866-1.356	0.484	1.057	0.847-1.320	0.622		-		0.989	0.865-1.131	0.872	0.991	0.868-1.131	0.890
Middle		-		1.325	1.028-1.707	**0.030**	1.257	0.978-1.616	***0.074***		-		0.963	0.835-1.110	0.603	0.969	0.840-1.116	0.660
Second highest		-		1.574	1.209-2.049	**0.001**	1.475	1.134-1.919	**0.004**		-		1.001	0.874-1.146	0.987	1.012	0.884-1.159	0.863
Highest		-		1.662	1.159-2.384	**0.006**	1.516	1.056-2.175	**0.024**		-		1.003	0.880-1.144	0.959	1.019	0.893-1.163	0.779
Job status (NS-SEC)						**0.001**			**0.003**						**<0.001**			**0.001**
Not applicable		-		1.000	(ref.)	.	1.000	(ref.)	.		-		1.000	(ref.)	.	1.000	(ref.)	.
Routine and manual		-		1.114	0.831-1.494	0.470	1.111	0.827-1.493	0.484		-		1.077	0.857-1.353	0.524	1.080	0.858-1.359	0.513
Intermediate		-		1.352	0.962-1.901	***0.083***	1.325	0.941-1.864	0.107		-		0.871	0.680-1.114	0.271	0.875	0.683-1.121	0.292
Higher managerial, admin and professional		-		1.664	1.174-2.358	**0.004**	1.610	1.136-2.283	**0.007**		-		0.847	0.679-1.058	0.144	0.855	0.684-1.069	0.170
Education (highest qualification)						**<0.001**			**<0.001**						**<0.001**			**<0.001**
None		-		1.000	(ref.)	.	1.000	(ref.)	.		-		1.000	(ref.)	.	1.000	(ref.)	.
Level 1 or 2		-		1.579	1.284-1.942	**<0.001**	1.554	1.264-1.912	**<0.001**		-		0.779	0.678-0.896	**<0.001**	0.781	0.680-0.897	**<0.001**
Levels 3 to 5 (inc. other and overseas)		-		2.236	1.784-2.802	**<0.001**	2.198	1.751-2.761	**<0.001**		-		0.582	0.491-0.690	**<0.001**	0.584	0.493-0.691	**<0.001**
Level 6 plus		-		4.478	3.296-6.082	**<0.001**	4.364	3.205-5.943	**<0.001**		-		0.506	0.428-0.598	**<0.001**	0.508	0.430-0.600	**<0.001**
Constant	1.860	1.438-2.407	**<0.001**	0.657	0.433-0.997	**0.048**	0.187	0.099-0.354	**<0.001**	0.611	0.510-0.731	**<0.001**	0.949	0.709-1.268	0.722	1.154	0.832-1.601	0.391

N	12,673			12,651			12,651			8,742			8,725			8,725		
Food shops and supermarkets that are easy to get to			0.230			0.435			0.253			0.246			0.226			0.328
Not at all common	0.931	0.720-1.203	0.583	0.962	0.744-1.245	0.771	0.916	0.707-1.187	0.506	0.872	0.753-1.011	***0.069***	0.872	0.750-1.015	***0.077***	0.885	0.762-1.029	0.111
Not very common	0.840	0.692-1.020	***0.078***	0.874	0.717-1.065	0.181	0.842	0.691-1.027	***0.091***	0.965	0.838-1.111	0.617	0.950	0.823-1.096	0.483	0.958	0.828-1.108	0.559
Fairly common	0.894	0.778-1.028	0.116	0.911	0.794-1.045	0.184	0.896	0.781-1.028	0.117	0.969	0.908-1.034	0.342	0.962	0.900-1.029	0.262	0.964	0.901-1.032	0.296
Very common	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.
Income (OECD equivalised quintiles)						**0.022**			***0.069***						0.846			0.745
Lowest		-		1.000	(ref.)	.	1.000	(ref.)	.		-		1.000	(ref.)	.	1.000	(ref.)	.
Second lowest		-		1.038	0.832-1.294	0.742	1.015	0.816-1.263	0.893		-		0.968	0.846-1.107	0.635	0.970	0.849-1.108	0.653
Middle		-		1.261	0.985-1.613	***0.066***	1.202	0.942-1.534	0.139		-		0.953	0.832-1.092	0.487	0.959	0.838-1.098	0.547
Second highest		-		1.498	1.156-1.941	**0.002**	1.413	1.091-1.830	**0.009**		-		0.976	0.854-1.116	0.724	0.988	0.866-1.129	0.864
Highest		-		1.478	1.047-2.085	**0.026**	1.360	0.964-1.920	***0.080***		-		1.002	0.879-1.142	0.974	1.021	0.894-1.165	0.762
Job status (NS-SEC)						**0.002**			**0.004**						**<0.001**			**<0.001**
Not applicable		-		1.000	(ref.)	.	1.000	(ref.)	.		-		1.000	(ref.)	.	1.000	(ref.)	.
Routine and manual		-		1.086	0.814-1.449	0.575	1.072	0.803-1.432	0.635		-		1.073	0.864-1.333	0.526	1.075	0.863-1.338	0.519
Intermediate		-		1.294	0.932-1.798	0.124	1.263	0.910-1.752	0.163		-		0.838	0.666-1.053	0.130	0.841	0.668-1.059	0.141
Higher managerial, admin and professional		-		1.558	1.107-2.191	**0.011**	1.499	1.067-2.105	**0.019**		-		0.832	0.675-1.024	***0.083***	0.838	0.680-1.034	***0.100***
Education (highest qualification)						**<0.001**			**<0.001**						**<0.001**			**<0.001**
None		-		1.000	(ref.)	.	1.000	(ref.)	.		-		1.000	(ref.)	.	1.000	(ref.)	.
Level 1 or 2		-		1.634	1.338-1.997	**<0.001**	1.604	1.312-1.959	**<0.001**		-		0.810	0.710-0.925	**0.002**	0.812	0.712-0.926	**0.002**

Levels 3 to 5 (inc. other and overseas)		-		2.423	1.945-3.019	**<0.001**	2.377	1.905-2.965	**<0.001**		-		0.634	0.545-0.738	**<0.001**	0.635	0.546-0.739	**<0.001**
Level 6 plus		-		4.504	3.333-6.086	**<0.001**	4.360	3.222-5.899	**<0.001**		-		0.551	0.475-0.638	**<0.001**	0.553	0.478-0.641	**<0.001**
Constant	2.069	1.655-2.587	**<0.001**	0.748	0.502-1.113	0.152	0.194	0.112-0.335	**<0.001**	0.595	0.505-0.701	**<0.001**	0.898	0.684-1.178	0.438	1.087	0.799-1.478	0.595
N	14,177			14,152			14,152			9,873			9,854			9,854		
Volume of traffic			0.303			0.398			0.384			0.566			0.570			0.530
Heavy	1.422	0.985-2.051	***0.060***	1.375	0.947-1.995	***0.094***	1.400	0.956-2.052	***0.084***	0.951	0.823-1.099	0.499	0.950	0.817-1.106	0.509	0.945	0.814-1.098	0.462
Moderate	0.974	0.818-1.161	0.773	0.979	0.822-1.166	0.810	0.985	0.826-1.174	0.865	0.945	0.866-1.032	0.206	0.943	0.862-1.031	0.198	0.941	0.860-1.030	0.188
Light	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.	1.000	(ref.)	.
No traffic permitted	1.002	0.761-1.319	0.989	1.030	0.783-1.355	0.833	1.008	0.767-1.323	0.956	0.973	0.863-1.096	0.648	0.985	0.875-1.109	0.803	0.992	0.882-1.116	0.890
Income (OECD equivalised quintiles)						**0.029**			***0.085***						0.972			0.931
Lowest		-		1.000	(ref.)	.	1.000	(ref.)	.		-		1.000	(ref.)	.	1.000	(ref.)	.
Second lowest		-		1.012	0.814-1.259	0.914	0.989	0.797-1.227	0.922		-		0.982	0.857-1.126	0.800	0.985	0.861-1.127	0.824
Middle		-		1.249	0.986-1.583	***0.066***	1.190	0.941-1.503	0.146		-		0.968	0.841-1.113	0.647	0.976	0.849-1.121	0.729
Second highest		-		1.462	1.127-1.896	**0.004**	1.378	1.063-1.787	**0.016**		-		0.984	0.857-1.130	0.822	0.997	0.869-1.144	0.968
Highest		-		1.432	1.020-2.012	**0.038**	1.315	0.936-1.849	0.115		-		0.998	0.874-1.140	0.982	1.018	0.890-1.164	0.797
Job status (NS-SEC)						**0.005**			**0.012**						**<0.001**			**<0.001**
Not applicable		-		1.000	(ref.)	.	1.000	(ref.)	.		-		1.000	(ref.)	.	1.000	(ref.)	.
Routine and manual		-		1.076	0.789-1.469	0.643	1.064	0.779-1.453	0.698		-		1.054	0.847-1.311	0.639	1.056	0.847-1.317	0.627
Intermediate		-		1.253	0.870-1.805	0.225	1.222	0.849-1.758	0.281		-		0.817	0.650-1.027	***0.083***	0.821	0.652-1.034	***0.093***
Higher managerial, admin and professional		-		1.536	1.058-2.229	**0.024**	1.478	1.019-2.143	**0.039**		-		0.808	0.656-0.996	**0.046**	0.815	0.660-1.006	***0.057***

Education (highest qualification)						**<0.001**			**<0.001**						**<0.001**			**<0.001**
None		-		1.000	(ref.)	.	1.000	(ref.)	.		-		1.000	(ref.)	.	1.000	(ref.)	.
Level 1 or 2		-		1.636	1.332-2.009	**<0.001**	1.604	1.307-1.970	**<0.001**		-		0.814	0.709-0.934	**0.003**	0.815	0.711-0.935	**0.003**
Levels 3 to 5 (inc. other and overseas)		-		2.398	1.921-2.995	**<0.001**	2.347	1.879-2.933	**<0.001**		-		0.642	0.548-0.751	**<0.001**	0.643	0.550-0.752	**<0.001**
Level 6 plus		-		4.434	3.280-5.993	**<0.001**	4.285	3.168-5.797	**<0.001**		-		0.556	0.477-0.648	**<0.001**	0.559	0.480-0.650	**<0.001**
Constant	1.961	1.555-2.473	**<0.001**	0.738	0.480-1.136	0.168	0.186	0.106-0.327	**<0.001**	0.587	0.497-0.693	**<0.001**	0.891	0.681-1.167	0.401	1.135	0.824-1.563	0.440
N	13,782			13,757			13,757			9,594			9,575			9,575		

Simplified model results, showing only results for local environmental quality measures and SES indicators. M1 adjusted for exposure to current environment, infant and maternal characteristics. M2 adjusted for exposure to current environment, infant and maternal characteristics and income, job status and education. M3 adjusted for exposure to current environment, infant and maternal characteristics, income, job status, education and ward-level contextual factors. Each model includes one environmental quality measure only. P-values ≤0.05 shown in bold and p-values between 0.05 and 0.1 shown in bold italic. Hazard ratios represent breastfeeding termination rather than duration. The number of observations (N) varies between models due to differing levels of missing data. Results are weighted to allow for the complex survey design and models are hierarchical to control for the clustering at ward-level. OR=Odds Ratio. HR=Hazard Ratio. CI=Confidence Interval. P-val.=P-value. Env.=Environmental. OECD=Organisation for Economic Co-operation and Development. NS-SEC=National Statistics Socio-economic Classification. Education measured by highest qualification level. If mothers are partnered, highest of mother's and partner's SES used.

B. SUPPLEMENTARY MATERIAL FOR STUDY 2

B.1 Results – additional detail

Table B.1: Environmental quality correlation matrices

a) White British mothers only (n=3,951), restricted to those not missing data on breastfeeding initiation

	Total trihalomethanes °	**Brominated trihalomethanes °**	**Bromodichloromethane °**	**Dibromochloromethane °**	**Chloroform °**	**Nitrogen oxides ᶜ**	**Nitrogen dioxide ᶜ**	**Passive smoke ᵇ**	**No central heating ᵇ**
Brominated trihalomethanes °	0.973								
	<0.001								
	3,863								
Bromo-dichloromethane °	0.978	0.998							
	<0.001	**<0.001**							
	3,863	3,863							
Dibromo-chloromethane °	0.926	0.977	0.965						
	<0.001	**<0.001**	**<0.001**						
	3,863	3,863	3,863						
Chloroform °	0.999	0.964	0.969	0.914					
	<0.001	**<0.001**	**<0.001**	**<0.001**					
	3,863	3,863	3,863	3,863					
Nitrogen oxides ᶜ	0.007	0.033	0.023	0.055	0.005				
	0.713	***0.084***	0.228	**0.005**	0.816				
	3,749	3,749	3,749	3,749	3,749				
Nitrogen dioxide ᶜ	0.005	0.027	0.023	0.022	0.000	0.820			
	0.796	0.166	0.226	0.254	0.988	**<0.001**			
	3,749	3,749	3,749	3,749	3,749	3,809			
Passive smoke ᵇ	0.105	0.126	0.135	0.077	0.102	0.057	0.103		
	<0.001	**<0.001**	**<0.001**	**0.001**	**<0.001**	**0.008**	**<0.001**		
	3,850	3,850	3,850	3,850	3,850	3,794	3,794		
No central heating ᵇ	0.017	0.108	0.096	0.102	0.019	0.076	0.086	0.165	
	0.841	0.201	0.259	0.227	0.819	0.299	0.244	***0.073***	
	819	819	819	819	819	796	796	833	
Damp and/or mould ᵇ	-0.024	-0.038	-0.039	-0.049	-0.022	-0.041	-0.057	0.125	0.000
	0.644	0.453	0.441	0.337	0.672	0.388	0.215	**0.025**	0.997
	986	986	986	986	986	965	965	1,012	832

Strong correlation against predicted — *No correlation* — *Strong correlation in predicted direction* *b) Pakistani-origin mothers only (n=4,411), restricted to those not missing data on breastfeeding initiation*

	Total trihalomethanes [o]	Brominated trihalomethanes [o]	Bromodichloromethane [o]	Dibromochloromethane [o]	Chloroform [o]	Nitrogen oxides [c]	Nitrogen dioxide [c]	Passive smoke [b]	No central heating [b]
Brominated trihalomethanes [o]	0.988								
	<0.001								
	4,341								
Bromo-dichloromethane [o]	0.990	0.999							
	<0.001	**<0.001**							
	4,341	4,341							
Dibromo-chloromethane [o]	0.954	0.984	0.978						
	<0.001	**<0.001**	**<0.001**						
	4,341	4,341	4,341						
Chloroform [o]	1.000	0.983	0.986	0.947					
	<0.001	**<0.001**	**<0.001**	**<0.001**					
	4,341	4,341	4,341	4,341					
Nitrogen oxides [c]	-0.034	-0.019	-0.025	0.008	-0.042				
	0.042	0.252	0.135	0.625	**0.013**				
	4,265	4,265	4,265	4,265	4,265				
Nitrogen dioxide [c]	-0.071	-0.056	-0.058	-0.051	-0.079	0.826			
	<0.001	**0.001**	**0.001**	**0.003**	**<0.001**	**<0.001**			
	4,265	4,265	4,265	4,265	4,265	4,313			
Passive smoke [b]	0.140	0.151	0.153	0.149	0.143	0.010	-0.002		
	<0.001	**<0.001**	**<0.001**	**<0.001**	**<0.001**	0.613	0.907		
	4,315	4,315	4,315	4,315	4,315	4,279	4,279		
No central heating [b]	-0.013	-0.010	0.006	0.013	-0.020	0.242	0.184	-0.110	
	0.856	0.889	0.932	0.862	0.780	**<0.001**	**0.002**	0.213	
	1,036	1,036	1,036	1,036	1,036	1,024	1,024	1,043	
Damp and/or mould [b]	-0.012	-0.009	-0.013	-0.032	-0.013	0.067	0.132	0.053	-0.082
	0.769	0.835	0.757	0.451	0.763	***0.070***	**<0.001**	0.286	0.365
	1,491	1,491	1,491	1,491	1,491	1,480	1,480	1,508	1,046

Strong correlation against predicted direction — *No correlation* — *Strong correlation in predicted direction* *c) Mothers of "other" ethnicities only (n=1,517), restricted to those not missing data on breastfeeding initiation*

	Total trihalomethanes [o]	**Brominated trihalomethanes [o]**	**Bromodichloromethane [o]**	**Dibromochloromethane [o]**	**Chloroform [o]**	**Nitrogen oxides [c]**	**Nitrogen dioxide [c]**	**Passive smoke [b]**	**No central heating [b]**
Brominated trihalomethanes [o]	0.981								
	<0.001								
	1,495								
Bromo-dichloromethane [o]	0.981	0.999							
	<0.001	**<0.001**							
	1,495	1,495							
Dibromo-chloromethane [o]	0.929	0.982	0.977						
	<0.001	**<0.001**	**<0.001**						
	1,495	1,495	1,495						
Chloroform [o]	1.000	0.975	0.975	0.918					
	<0.001	**<0.001**	**<0.001**	**<0.001**					
	1,495	1,495	1,495	1,495					
Nitrogen oxides [c]	-0.053	-0.032	-0.022	0.006	-0.051				
	0.064	0.257	0.436	0.842	***0.073***				
	1,474	1,474	1,474	1,474	1,474				
Nitrogen dioxide [c]	-0.096	-0.079	-0.066	-0.060	-0.092	0.838			
	<0.001	**0.003**	**0.015**	**0.027**	**0.001**	**<0.001**			
	1,474	1,474	1,474	1,474	1,474	1,489			
Passive smoke [b]	0.110	0.103	0.093	0.094	0.112	0.020	0.042		
	0.005	**0.008**	**0.017**	**0.016**	**0.004**	0.564	0.201		
	1,490	1,490	1,490	1,490	1,490	1,481	1,481		
No central heating [b]	0.097	0.131	0.124	0.147	0.067	0.029	-0.008	0.014	
	0.414	0.264	0.292	0.216	0.572	0.794	0.932	0.918	
	311	311	311	311	311	311	311	315	
Damp and/or mould [b]	0.016	0.043	0.059	0.054	0.013	0.033	0.026	-0.014	0.183
	0.842	0.595	0.462	0.502	0.867	0.666	0.702	0.884	0.189
	389	389	389	389	389	386	386	395	316

Strong correlation against predicted | *No correlation* | *Strong correlation in predicted direction* *d) All mothers (n=12,087), restricted to those not missing data on breastfeeding initiation*

	Total trihalomethanes ᵒ	Brominated trihalomethanes ᵒ	Bromodichloromethane ᵒ	Dibromochloromethane ᵒ	Chloroform ᵒ	Nitrogen oxides ᶜ	Nitrogen dioxide ᶜ	Passive smoke ᵇ	No central heating ᵇ
Brominated trihalomethanes ᵒ	0.982								
	<0.001								
	9,714								
Bromo-dichloromethane ᵒ	0.985	0.999							
	<0.001	**<0.001**							
	9,714	9,714							
Dibromo-chloromethane ᵒ	0.942	0.982	0.974						
	<0.001	**<0.001**	**<0.001**						
	9,714	9,714	9,714						
Chloroform ᵒ	1.000	0.975	0.979	0.932					
	<0.001	**<0.001**	**<0.001**	**<0.001**					
	9,714	9,714	9,714	9,714					
Nitrogen oxides ᶜ	-0.087	-0.076	-0.078	-0.044	-0.089				
	<0.001	**<0.001**	**<0.001**	**<0.001**	**<0.001**				
	9,503	9,503	9,503	9,503	9,503				
Nitrogen dioxide ᶜ	-0.109	-0.100	-0.097	-0.091	-0.111	0.837			
	<0.001	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**			
	9,503	9,503	9,503	9,503	9,503	9,629			
Passive smoke ᵇ	0.172	0.191	0.192	0.166	0.171	-0.034	-0.016		
	<0.001	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**0.011**	0.217		
	9,670	9,670	9,670	9,670	9,670	9,570	9,570		
No central heating ᵇ	0.012	0.048	0.050	0.058	0.004	0.146	0.121	0.011	
	0.816	0.336	0.315	0.238	0.939	**0.001**	**0.003**	0.844	
	2,168	2,168	2,168	2,168	2,168	2,133	2,133	2,193	
Damp and/or mould ᵇ	-0.009	-0.009	-0.009	-0.022	-0.009	0.022	0.050	0.074	0.000
	0.770	0.775	0.771	0.469	0.774	0.426	***0.053***	**0.031**	1.000
	2,869	2,869	2,869	2,869	2,869	2,835	2,835	2,918	2,196

Strong correlation against predicted — *No correlation* — *Strong correlation in predicted direction*

Correlation coefficients (first row, colour coded), P-value for likelihood ratio test of no correlation (second row, p<0.05 in bold, p<0.1 in bold italic), and number of observations (second row) for a) White British mothers only, b) Pakistan-origin mothers only, c) "other" ethnicity mothers only and d) all mothers. Polychoric correlations calculated for combinations of binary (ᵇ) and/or ordinal (ᵒ) variables, polyserial correlations calculated for combinations of continuous (ᶜ) and binary/ordinal variables, Pearson's correlations calculated for combinations of continuous variables.

Table B.2: Mediation results for breastfeeding initiation.

a) *All mothers*

	Birthweight				Head circumference				Abdominal circumference				Gestational age			
Physical environmental quality	**Est.**	**P-Val.**	**95% CI**		**Est.**	**P-Val.**	**95% CI**		**Est.**	**P-Val.**	**95% CI**		**Est.**	**P-Val.**	**95% CI**	
Water disinfectant by-product																
Total trihalomethanes	0.015	0.311	-0.014	0.043	0.015	0.325	-0.015	0.044	0.016	0.297	-0.014	0.046	0.015	0.308	-0.014	0.043
Indirect effect	0.000	0.759	-0.001	0.001	0.000	0.818	-0.001	0.001	0.000	0.529	-0.001	0.000	0.000	0.928	0.000	0.000
Brominated trihalomethanes	-0.068	0.553	-0.294	0.157	-0.063	0.596	-0.296	0.170	-0.072	0.554	-0.311	0.167	-0.068	0.555	-0.293	0.158
Indirect effect	0.001	0.806	-0.006	0.008	0.001	0.782	-0.005	0.006	-0.001	0.523	-0.005	0.003	0.000	0.915	-0.002	0.003
Bromodichloromethane	-0.084	0.566	-0.373	0.204	-0.075	0.623	-0.373	0.223	-0.088	0.572	-0.393	0.217	-0.084	0.570	-0.372	0.205
Indirect effect	0.001	0.784	-0.008	0.010	0.001	0.727	-0.006	0.008	-0.001	0.618	-0.006	0.004	0.000	0.915	-0.003	0.003
Dibromochloromethane	0.336	0.645	-1.093	1.766	0.315	0.676	-1.163	1.794	0.325	0.675	-1.195	1.845	0.344	0.637	-1.085	1.774
Indirect effect	0.011	0.629	-0.033	0.055	0.006	0.746	-0.028	0.039	-0.011	0.425	-0.040	0.017	0.000	0.925	-0.010	0.011
Chloroform	0.020	0.218	-0.012	0.052	0.020	0.234	-0.013	0.053	0.022	0.205	-0.012	0.056	0.020	0.216	-0.012	0.052
Indirect effect	0.000	0.754	-0.001	0.001	0.000	0.825	-0.001	0.001	0.000	0.533	-0.001	0.000	0.000	0.929	0.000	0.000
Air pollution																
Nitrogen oxides	-0.204	**<0.001**	-0.316	-0.093	-0.200	**0.001**	-0.316	-0.084	-0.221	**<0.001**	-0.339	-0.103	-0.207	**<0.001**	-0.318	-0.096
Indirect effect	-0.004	***0.078***	-0.008	0.000	-0.005	***0.097***	-0.010	0.001	-0.003	0.241	-0.009	0.002	0.000	0.992	-0.001	0.001
Nitrogen dioxide	-0.209	**<0.001**	-0.327	-0.091	-0.208	**0.001**	-0.330	-0.087	-0.238	**<0.001**	-0.362	-0.114	-0.211	**<0.001**	-0.328	-0.093
Indirect effect	-0.002	0.235	-0.006	0.002	-0.003	0.174	-0.006	0.001	-0.005	0.269	-0.014	0.004	0.000	0.980	0.000	0.000
Passive cigarette smoke	-0.033	0.531	-0.135	0.069	-0.034	0.534	-0.139	0.072	-0.028	0.614	-0.136	0.081	-0.035	0.504	-0.137	0.067
Indirect effect	-0.003	0.171	-0.006	0.001	-0.001	0.620	-0.003	0.002	0.001	0.382	-0.001	0.003	0.000	0.835	-0.001	0.001
Household condition																
No central heating	-0.210	0.400	-0.700	0.279	-0.236	0.352	-0.734	0.261	-0.264	0.299	-0.762	0.234	-0.239	0.336	-0.726	0.248
Indirect effect	-0.034	***0.092***	-0.074	0.006	0.002	0.904	-0.023	0.026	-0.005	0.539	-0.021	0.011	0.001	0.801	-0.006	0.008
Damp and/or mould	0.417	**0.002**	0.154	0.681	0.392	**0.004**	0.122	0.662	0.392	**0.005**	0.118	0.667	0.421	**0.002**	0.158	0.684
Indirect effect	0.003	0.743	-0.015	0.020	0.000	0.993	-0.002	0.002	0.000	0.885	-0.006	0.005	0.000	0.889	-0.001	0.002

b) White British mothers

	Birthweight				Head circumference				Abdominal circumference				Gestational age			
Physical environmental quality	**Est.**	**P-Val.**	**95% CI**		**Est.**	**P-Val.**	**95% CI**		**Est.**	**P-Val.**	**95% CI**		**Est.**	**P-Val.**	**95% CI**	
Water disinfectant by-product																
Total trihalomethanes	0.027	0.142	-0.009	0.064	0.025	0.189	-0.012	0.063	0.026	0.189	-0.013	0.065	0.027	0.143	-0.009	0.064
Indirect effect	0.000	0.811	-0.001	0.001	0.000	0.701	-0.001	0.001	0.000	0.933	0.000	0.000	0.000	0.561	-0.001	0.001
Brominated trihalomethanes	0.159	0.306	-0.146	0.465	0.156	0.332	-0.160	0.472	0.127	0.444	-0.198	0.451	0.159	0.307	-0.146	0.464
Indirect effect	-0.001	0.765	-0.008	0.006	0.000	0.929	-0.006	0.005	0.000	0.940	-0.002	0.002	0.002	0.561	-0.004	0.008
Bromodichloromethane	0.195	0.337	-0.203	0.593	0.194	0.357	-0.218	0.606	0.149	0.489	-0.274	0.573	0.195	0.338	-0.203	0.592
Indirect effect	-0.001	0.805	-0.010	0.008	0.000	0.984	-0.007	0.007	0.000	0.888	-0.002	0.003	0.002	0.546	-0.006	0.011
Dibromochloromethane	1.467	0.117	-0.366	3.300	1.392	0.152	-0.513	3.297	1.398	0.162	-0.564	3.361	1.465	0.117	-0.367	3.297
Indirect effect	-0.006	0.779	-0.048	0.036	-0.002	0.907	-0.036	0.032	0.000	0.935	-0.010	0.011	0.008	0.624	-0.024	0.040
Chloroform	0.032	0.131	-0.009	0.072	0.029	0.178	-0.013	0.072	0.031	0.169	-0.013	0.075	0.031	0.131	-0.009	0.072
Indirect effect	0.000	0.820	-0.001	0.001	0.000	0.678	-0.001	0.001	0.000	0.918	0.000	0.000	0.000	0.563	-0.001	0.001
Air pollution																
Nitrogen oxides	-0.092	0.357	-0.287	0.103	-0.070	0.498	-0.274	0.133	-0.055	0.605	-0.262	0.153	-0.096	0.337	-0.291	0.099
Indirect effect	-0.005	0.253	-0.014	0.004	-0.003	0.496	-0.011	0.006	0.000	0.852	-0.003	0.003	-0.004	0.402	-0.013	0.005
Nitrogen dioxide	-0.209	**0.044**	-0.414	-0.005	-0.213	**0.048**	-0.425	-0.002	-0.209	***0.058***	-0.425	0.007	-0.212	**0.042**	-0.416	-0.008
Indirect effect	-0.003	0.323	-0.010	0.003	-0.001	0.726	-0.004	0.002	0.000	0.956	-0.015	0.014	-0.003	0.425	-0.012	0.005
Passive cigarette smoke	-0.094	0.243	-0.253	0.064	-0.077	0.357	-0.241	0.087	-0.076	0.374	-0.244	0.092	-0.040	0.628	-0.202	0.122
Indirect effect	-0.008	***0.091***	-0.018	0.001	-0.002	0.370	-0.008	0.003	0.000	0.838	-0.004	0.004	0.000	0.947	-0.002	0.002
Household condition																
No central heating	-0.278	0.451	-1.001	0.445	-0.231	0.539	-0.967	0.505	-0.239	0.525	-0.975	0.497	-0.301	0.414	-1.022	0.421
Indirect effect	-0.016	0.470	-0.059	0.027	0.031	0.380	-0.038	0.100	-0.003	0.788	-0.021	0.016	-0.004	0.856	-0.042	0.035
Damp and/or mould	0.485	**0.017**	0.085	0.884	0.563	**0.008**	0.149	0.976	0.548	**0.011**	0.126	0.969	0.503	**0.014**	0.102	0.903
Indirect effect	0.003	0.687	-0.013	0.019	0.002	0.761	-0.013	0.017	0.000	0.973	-0.002	0.002	0.000	0.884	-0.004	0.004

c) Pakistani-origin mothers

	Birthweight				Head circumference				Abdominal circumference				Gestational age			
Physical environmental quality	**Est.**	**P-Val.**	**95% CI**		**Est.**	**P-Val.**	**95% CI**		**Est.**	**P-Val.**	**95% CI**		**Est.**	**P-Val.**	**95% CI**	
Water disinfectant by-product																
Total trihalomethanes	-0.043	0.122	-0.098	0.012	-0.040	0.158	-0.097	0.016	-0.053	***0.078***	-0.111	0.006	-0.045	0.106	-0.101	0.010
Indirect effect	-0.002	0.183	-0.005	0.001	0.000	0.681	-0.002	0.001	0.000	0.548	-0.001	0.002	0.000	0.819	0.000	0.000
Brominated trihalomethanes	-0.661	**0.002**	-1.074	-0.249	-0.645	**0.003**	-1.069	-0.221	-0.726	**0.001**	-1.163	-0.290	-0.679	**0.001**	-1.093	-0.266
Indirect effect	-0.015	0.163	-0.036	0.006	-0.005	0.476	-0.018	0.008	0.003	0.631	-0.008	0.013	0.000	0.964	-0.002	0.002
Bromodichloromethane	-0.785	**0.003**	-1.296	-0.273	-0.765	**0.004**	-1.292	-0.238	-0.858	**0.002**	-1.399	-0.317	-0.806	**0.002**	-1.320	-0.293
Indirect effect	-0.018	0.183	-0.044	0.008	-0.005	0.515	-0.021	0.011	0.003	0.597	-0.009	0.016	0.000	0.988	-0.003	0.003
Dibromochloromethane	-3.531	**0.017**	-6.437	-0.626	-3.356	**0.026**	-6.319	-0.392	-4.186	**0.008**	-7.264	-1.107	-3.638	**0.014**	-6.548	-0.727
Indirect effect	-0.099	0.195	-0.249	0.051	-0.036	0.451	-0.130	0.058	0.016	0.660	-0.056	0.088	-0.001	0.875	-0.019	0.016
Chloroform	-0.041	0.199	-0.104	0.022	-0.038	0.249	-0.102	0.027	-0.052	0.130	-0.119	0.015	-0.044	0.176	-0.107	0.020
Indirect effect	-0.002	0.189	-0.006	0.001	0.000	0.721	-0.002	0.002	0.001	0.538	-0.001	0.002	0.000	0.805	0.000	0.001
Air pollution																
Nitrogen oxides	-0.320	**<0.001**	-0.478	-0.162	-0.321	**<0.001**	-0.484	-0.158	-0.350	**<0.001**	-0.518	-0.182	-0.315	**<0.001**	-0.472	-0.157
Indirect effect	0.004	0.303	-0.004	0.012	-0.004	0.258	-0.010	0.003	-0.007	0.333	-0.022	0.008	-0.001	0.661	-0.003	0.002
Nitrogen dioxide	-0.243	**0.005**	-0.412	-0.073	-0.239	**0.008**	-0.414	-0.063	-0.267	**0.004**	-0.447	-0.087	-0.236	**0.006**	-0.405	-0.066
Indirect effect	0.006	0.197	-0.003	0.015	0.000	0.943	-0.006	0.005	-0.009	0.301	-0.027	0.008	-0.001	0.630	-0.004	0.002
Passive cigarette smoke	-0.031	0.688	-0.181	0.120	-0.027	0.739	-0.183	0.129	-0.022	0.785	-0.182	0.138	-0.008	0.916	-0.160	0.144
Indirect effect	-0.004	0.332	-0.011	0.004	-0.002	0.425	-0.007	0.003	0.002	0.453	-0.003	0.006	0.000	0.906	-0.003	0.003
Household condition																
No central heating	-0.440	0.235	-1.167	0.287	-0.539	0.147	-1.268	0.190	-0.018	0.650	-0.098	0.061	-0.488	0.186	-1.211	0.236
Indirect effect	-0.045	0.291	-0.129	0.039	-0.001	0.903	-0.012	0.011	-0.011	0.660	-0.062	0.039	0.014	0.572	-0.035	0.063
Damp and/or mould	0.347	***0.077***	-0.038	0.733	0.219	0.268	-0.168	0.606	0.237	0.236	-0.155	0.629	0.345	***0.078***	-0.039	0.728
Indirect effect	-0.009	0.656	-0.046	0.029	-0.002	0.683	-0.011	0.007	0.004	0.531	-0.009	0.018	0.002	0.718	-0.010	0.014

Models controlling for maternal age, immigration status, smoking during pregnancy, BMI, parity, infant sex, singleton/multiple birth, cohabitation status and socioeconomic position. Birthweight, head circumference and abdominal circumference models additionally controlling for gestational age. One physical environmental quality indicator included per model, first line representing its direct effect on breastfeeding initiation and the second line its indirect effect through one of the four birth outcomes. Significant indirect associations at the 10% level (p≤0.10) highlighted in yellow. Negative coefficients indicate reduced odds of initiation, positive coefficients indicate increased odds. CI=confidence interval.

Table B.3: Mediation results for breastfeeding duration.

a) All mothers

	Birthweight				Head circumference				Abdominal circumference				Gestational age			
Physical environmental quality	**Est.**	**P-Val.**	**95% CI**		**Est.**	**P-Val.**	**95% CI**		**Est.**	**P-Val.**	**95% CI**		**Est.**	**P-Val.**	**95% CI**	
Water disinfectant by-product																
Total trihalomethanes	0.006	0.657	-0.020	0.032	0.002	0.878	-0.025	0.029	0.000	0.994	-0.028	0.028	0.006	0.661	-0.020	0.032
Indirect effect	0.000	0.767	0.000	0.000	0.000	0.823	0.000	0.000	0.000	0.787	0.000	0.000	0.000	0.670	0.000	0.000
Brominated trihalomethanes	0.010	0.926	-0.197	0.216	-0.017	0.876	-0.228	0.195	-0.036	0.747	-0.253	0.181	0.010	0.926	-0.196	0.216
Indirect effect	0.000	0.811	-0.002	0.002	0.000	0.791	-0.002	0.002	0.000	0.793	-0.002	0.001	0.001	0.436	-0.002	0.005
Bromodichloromethane	-0.004	0.976	-0.267	0.259	-0.039	0.778	-0.309	0.231	-0.063	0.658	-0.339	0.214	-0.004	0.976	-0.267	0.259
Indirect effect	0.000	0.790	-0.003	0.002	0.000	0.744	-0.003	0.002	0.000	0.805	-0.002	0.001	0.002	0.421	-0.003	0.006
Dibromochloromethane	0.330	0.618	-0.967	1.627	0.152	0.823	-1.183	1.487	0.037	0.958	-1.336	1.410	0.325	0.623	-0.971	1.622
Indirect effect	-0.003	0.659	-0.019	0.012	-0.002	0.759	-0.016	0.012	-0.002	0.777	-0.017	0.013	0.006	0.563	-0.014	0.025
Chloroform	0.008	0.624	-0.022	0.038	0.003	0.844	-0.028	0.034	0.001	0.969	-0.031	0.032	0.007	0.627	-0.023	0.037
Indirect effect	0.000	0.763	0.000	0.000	0.000	0.830	0.000	0.000	0.000	0.786	0.000	0.000	0.000	0.721	0.000	0.000
Air pollution																
Nitrogen oxides	-0.067	0.188	-0.167	0.033	-0.092	***0.078***	-0.194	0.010	-0.101	***0.059***	-0.206	0.004	-0.067	0.190	-0.167	0.033
Indirect effect	0.001	0.362	-0.001	0.004	0.002	0.474	-0.003	0.006	-0.001	0.728	-0.005	0.003	0.000	0.640	-0.002	0.001
Nitrogen dioxide	-0.145	**0.004**	-0.244	-0.047	-0.156	**0.002**	-0.256	-0.056	-0.168	**0.001**	-0.270	-0.065	-0.146	**0.004**	-0.244	-0.047
Indirect effect	0.001	0.436	-0.001	0.003	0.001	0.511	-0.002	0.003	-0.001	0.884	-0.008	0.007	0.000	0.887	-0.002	0.001
Passive cigarette smoke	0.108	**0.018**	0.019	0.198	0.101	**0.031**	0.009	0.193	0.108	**0.025**	0.013	0.202	0.107	**0.019**	0.018	0.197
Indirect effect	0.001	0.429	-0.001	0.002	0.000	0.714	-0.001	0.001	0.000	0.933	-0.001	0.001	-0.001	0.474	-0.002	0.001
Household condition																
No central heating	-0.091	0.411	-0.309	0.126	-0.098	0.390	-0.321	0.125	-0.140	0.228	-0.366	0.087	-0.087	0.433	-0.303	0.130
Indirect effect	0.003	0.645	-0.008	0.013	-0.002	0.653	-0.013	0.008	0.000	0.971	-0.004	0.004	0.001	0.775	-0.005	0.007
Damp and/or mould	-0.053	0.320	-0.158	0.052	-0.045	0.414	-0.155	0.064	-0.046	0.423	-0.157	0.066	-0.054	0.313	-0.159	0.051
Indirect effect	0.000	0.764	-0.002	0.001	0.000	0.934	-0.001	0.001	0.000	0.920	0.000	0.000	0.000	0.873	-0.002	0.002

b) White British mothers

	Birthweight				Head circumference				Abdominal circumference				Gestational age			
Physical environmental quality	**Est.**	**P-Val.**	**95% CI**		**Est.**	**P-Val.**	**95% CI**		**Est.**	**P-Val.**	**95% CI**		**Est.**	**P-Val.**	**95% CI**	
Water disinfectant by-product																
Total trihalomethanes	-0.006	0.780	-0.046	0.035	-0.012	0.568	-0.054	0.030	-0.015	0.477	-0.058	0.027	-0.006	0.780	-0.046	0.035
Indirect effect	0.000	0.842	0.000	0.000	0.000	0.894	0.000	0.000	0.000	0.931	0.000	0.000	0.001	0.434	-0.001	0.003
Brominated trihalomethanes	-0.089	0.584	-0.409	0.231	-0.120	0.476	-0.450	0.210	-0.149	0.388	-0.486	0.189	-0.090	0.582	-0.410	0.230
Indirect effect	0.000	0.819	-0.003	0.002	0.000	0.937	-0.001	0.001	0.000	0.938	-0.003	0.003	0.006	0.436	-0.009	0.021
Bromodichloromethane	-0.139	0.517	-0.560	0.282	-0.177	0.423	-0.612	0.257	-0.217	0.337	-0.661	0.227	-0.140	0.515	-0.561	0.281
Indirect effect	0.000	0.840	-0.003	0.002	0.000	0.984	-0.001	0.001	0.000	0.876	-0.005	0.004	0.008	0.404	-0.011	0.028
Dibromochloromethane	-0.231	0.806	-2.072	1.610	-0.412	0.671	-2.319	1.494	-0.545	0.583	-2.490	1.401	-0.235	0.803	-2.075	1.606
Indirect effect	-0.002	0.825	-0.015	0.012	0.000	0.927	-0.006	0.006	-0.001	0.932	-0.020	0.018	0.027	0.553	-0.062	0.116
Chloroform	-0.005	0.814	-0.051	0.040	-0.013	0.588	-0.060	0.034	-0.017	0.498	-0.065	0.031	-0.005	0.814	-0.051	0.040
Indirect effect	0.000	0.847	0.000	0.000	0.000	0.895	0.000	0.000	0.000	0.914	0.000	0.000	0.001	0.438	-0.001	0.003
Air pollution																
Nitrogen oxides	-0.179	***0.071***	-0.373	0.015	-0.187	***0.065***	-0.386	0.012	-0.197	***0.057***	-0.400	0.006	-0.180	***0.069***	-0.374	0.014
Indirect effect	-0.001	0.731	-0.009	0.006	-0.001	0.750	-0.009	0.006	0.000	0.729	-0.002	0.003	-0.010	***0.074***	-0.021	0.001
Nitrogen dioxide	-0.291	**0.003**	-0.484	-0.098	-0.295	**0.003**	-0.492	-0.097	-0.309	**0.003**	-0.510	-0.108	-0.292	**0.003**	-0.485	-0.100
Indirect effect	-0.001	0.811	-0.006	0.004	0.000	0.805	-0.002	0.002	0.004	0.527	-0.009	0.017	-0.010	***0.085***	-0.021	0.001
Passive cigarette smoke	0.057	0.482	-0.102	0.216	0.042	0.612	-0.121	0.206	0.040	0.643	-0.128	0.207	0.059	0.471	-0.101	0.218
Indirect effect	-0.002	0.589	-0.010	0.005	-0.001	0.709	-0.004	0.003	-0.001	0.527	-0.005	0.003	0.000	0.946	-0.007	0.008
Household condition																
No central heating	-0.026	0.904	-0.454	0.401	-0.012	0.955	-0.445	0.420	-0.042	0.847	-0.473	0.389	-0.042	0.848	-0.468	0.384
Indirect effect	-0.007	0.511	-0.029	0.015	-0.013	0.465	-0.046	0.021	0.001	0.795	-0.007	0.009	-0.027	0.230	-0.071	0.017
Damp and/or mould	-0.077	0.428	-0.268	0.114	-0.090	0.370	-0.285	0.106	-0.087	0.397	-0.289	0.115	-0.076	0.437	-0.267	0.115
Indirect effect	0.001	0.698	-0.005	0.008	-0.001	0.776	-0.005	0.004	0.000	0.878	-0.005	0.004	0.002	0.794	-0.014	0.019

c) Pakistani-origin mothers

	Birthweight				Head circumference				Abdominal circumference				Gestational age			
Physical environmental quality	**Est.**	**P-Val.**	**95% CI**		**Est.**	**P-Val.**	**95% CI**		**Est.**	**P-Val.**	**95% CI**		**Est.**	**P-Val.**	**95% CI**	
Water disinfectant by-product																
Total trihalomethanes	0.007	0.729	-0.035	0.050	0.005	0.807	-0.037	0.048	0.005	0.815	-0.040	0.051	0.009	0.693	-0.034	0.051
Indirect effect	0.001	0.237	-0.001	0.003	0.000	0.693	-0.001	0.001	0.000	0.612	-0.001	0.001	0.000	0.762	-0.001	0.001
Brominated trihalomethanes	0.038	0.816	-0.281	0.357	0.008	0.960	-0.316	0.332	0.016	0.927	-0.321	0.352	0.046	0.778	-0.272	0.363
Indirect effect	0.009	0.218	-0.005	0.022	0.003	0.526	-0.006	0.012	0.001	0.669	-0.004	0.006	0.000	0.964	-0.006	0.005
Bromodichloromethane	0.035	0.862	-0.361	0.431	0.000	0.999	-0.402	0.401	0.009	0.966	-0.406	0.425	0.045	0.824	-0.349	0.438
Indirect effect	0.010	0.236	-0.006	0.026	0.003	0.556	-0.007	0.014	0.002	0.646	-0.005	0.008	0.000	0.988	-0.007	0.007
Dibromochloromethane	0.447	0.695	-1.789	2.684	0.150	0.897	-2.128	2.428	0.191	0.876	-2.214	2.597	0.462	0.685	-1.768	2.692
Indirect effect	0.055	0.246	-0.038	0.148	0.021	0.508	-0.042	0.085	0.007	0.690	-0.029	0.043	-0.004	0.859	-0.042	0.035
Chloroform	0.009	0.718	-0.040	0.057	0.007	0.785	-0.042	0.056	0.007	0.799	-0.045	0.059	0.010	0.681	-0.038	0.058
Indirect effect	0.001	0.242	-0.001	0.003	0.000	0.730	-0.001	0.001	0.000	0.606	-0.001	0.001	0.000	0.729	-0.001	0.001
Air pollution																
Nitrogen oxides	0.026	0.713	-0.112	0.163	-0.001	0.988	-0.141	0.139	0.002	0.978	-0.142	0.146	0.022	0.754	-0.115	0.159
Indirect effect	-0.002	0.341	-0.007	0.002	0.002	0.336	-0.003	0.007	-0.005	0.409	-0.016	0.007	0.000	0.794	-0.002	0.002
Nitrogen dioxide	-0.040	0.572	-0.177	0.098	-0.059	0.407	-0.199	0.081	-0.069	0.343	-0.212	0.074	-0.046	0.508	-0.184	0.091
Indirect effect	-0.003	0.256	-0.008	0.002	0.000	0.944	-0.003	0.003	-0.005	0.469	-0.019	0.009	0.000	0.785	-0.003	0.002
Passive cigarette smoke	0.080	0.219	-0.047	0.206	0.065	0.327	-0.065	0.194	0.067	0.325	-0.066	0.200	0.078	0.229	-0.049	0.205
Indirect effect	0.002	0.363	-0.002	0.007	0.001	0.513	-0.002	0.004	0.001	0.597	-0.002	0.003	0.001	0.486	-0.002	0.004
Household condition																
No central heating	-0.046	0.769	-0.355	0.263	-0.052	0.750	-0.368	0.265	-0.106	0.521	-0.430	0.218	-0.035	0.822	-0.344	0.273
Indirect effect	0.008	0.379	-0.010	0.025	0.000	0.958	-0.001	0.002	-0.002	0.837	-0.021	0.017	-0.011	0.313	-0.033	0.011
Damp and/or mould	0.008	0.914	-0.139	0.155	-0.010	0.894	-0.164	0.143	-0.003	0.971	-0.161	0.155	0.008	0.919	-0.140	0.155
Indirect effect	0.002	0.664	-0.006	0.009	0.001	0.707	-0.003	0.004	0.001	0.643	-0.003	0.005	-0.003	0.378	-0.011	0.004

Models controlling for maternal age, immigration status, smoking during pregnancy, BMI, parity, infant sex, singleton/multiple birth, cohabitation status and socioeconomic position. Birthweight, head circumference and abdominal circumference models additionally controlling for gestational age. One physical environmental quality indicator included per model, first line representing its direct effect on breastfeeding duration and the second line its indirect effect through one of the four birth outcomes. Significant indirect associations at the 10% level (p≤0.10) highlighted in yellow. Negative coefficients indicate a protective effect on duration (i.e. a reduced hazard of stopping breastfeeding), positive coefficients indicate a deleterious effect (i.e. an increased hazard of stopping breastfeeding). CI=confidence interval.

C. SUPPLEMENTARY MATERIAL FOR STUDY 3

C.1 Methods – additional detail

C.1.1 Main analysis

MCS sample model fit comparison was based on models adjusted for clustering and probability weights, but not stratification. This is because goodness of fit statistics could not be calculated for survey-set models which took this aspect of the MCS survey design into account. We were however able to use the Stata *svy* prefix command to estimate class membership probabilities and predict indicator probabilities and means, and so the complex survey design is fully taken into account in our main analyses.

Whilst conditional independence is technically an assumption of latent class analysis, we permitted residual associations between life history indicators within each latent class (Hallquist & Wright, 2014; Masyn, 2013; Ng & Schechter, 2017). When models did not converge, we used the *nonrtolerance* option, used parameter estimates from simpler models as starting values, and constrained binary indicators to +/-15 when probabilities were very close to 0 or 1 as necessary (Ng, 2018; Ng & Schechter, 2017).

C.1.2 BiB Sensitivity analysis

Any records missing data on covariates, groups, clusters or weights were excluded as this type of missingness is not permitted in latent class analysis (Lanza, Dziak, Huang, Wagner, & Collins, 2015). Indicators are allowed to have missing data and this is assumed to be missing at random. Many of our BiB indicators were however not missing at random as they were derived from questions only asked in the smaller sub-cohorts. We therefore conducted a sensitivity analysis in which we restricted our sample to mothers who were in at least one of the sub-cohorts, checking how the model fit statistics and two class model response profiles compared to the full sample. Results of this sensitivity analysis are presented in Tables C.2 and C.3.

C.1.3 Supplementary analysis: building up models by trait groupings

As a supplementary analysis, we also explored the extent of dichotomous trait clustering by building up a two class model one domain at a time, starting with postnatal parental investment indicators only and then adding successively more indicators, and again comparing the model fit criteria and probability estimates for these different models (results presented in Table C.4).

C.1.4 Predicting life history strategy with socioeconomic and environmental characteristics

As a preliminary step before exploring how class membership from the two class models were predicted by socioeconomic and environmental conditions, we ran polychoric correlations to explore how interrelated our different measures of environmental harshness and socioeconomic disadvantage were.

We reversed then standardised the factor scores used in our previous MCS analysis to transform the two measures of objective and subjective environmental quality into indicators of relative environmental harshness.

C.2 Results – additional detail

C.2.1 Predicting life history strategy with socioeconomic and environmental characteristics

Socioeconomic and environmental indicators were broadly correlated with one another in the anticipated direction, with greater disadvantage being positively associated with greater harshness (Tables C.5 and C.6). Parental death was however associated with parental separation in the opposite to anticipated direction in both MCS groups – women whose parents(s) had died were less likely to have experienced parental separation when a child. This could suggest that their parent(s) may have died before they were born. Parental death was also weakly negatively correlated with socioeconomic disadvantage and subjective environmental harshness in the MCS White group and with objective environmental harshness in the MCS Pakistani group. The BiB sample also had a few negative correlations. Seven correlations were in the opposite to anticipated direction amongst the Pakistani mothers in this sample, the strongest of which was between increased passive cigarette smoke exposure and decreased chances of not having central heating (-0.096). The White mothers in the MCS had four correlations going in the opposite to predicted direction, with the strongest being between household damp and mould and air pollution exposure (-0.068). The MCS White UK-born mothers had the most correlations of at least +/-0.30 (i.e. at least of moderate strength) between socioeconomic and environmental indicators whilst the BiB Pakistani mothers had the least. Correlations were generally stronger in the MCS sample than in the BiB sample and in the White groups than in the Pakistani groups.

C.2.2 BiB sensitivity analyses restricted to mothers in sub-cohorts

Analyses restricted to sub-cohort mothers were largely substantively similar to our BiB analyses on the full sample although there were some differences. Model fit improved with increasing number of classes as in the main analyses but one additional model did not converge (the four class model for White British mothers). For White British mothers, the two class model had the clearest class separation in both the main and sensitivity analyses, but for Pakistani mothers the clearest class separation was in the 3 class model in the main analyses but in the 4 class model in the sensitivity analyses. In the 2 class models, 51% of the White British sample was predicted to be in the fast class and 49% in the slow class, and these figures were 52% and 48% in the sensitivity analysis, respectively. Estimated means and probabilities showed the same patterns across the two classes in both analyses for White British mothers, but a few more confidence intervals were overlapping in the sensitivity analyses than in the main analyses (drinking alcohol, reading 2-4 days per week and giving no vaccinations) suggesting that the differences between the two classes may not be as pronounced as indicated in the main analyses. For Pakistani-origin mothers, 52% were predicted to be in the fast class and 48% in the slow class and these figures were 47% and 53% in the sensitivity analysis, respectively.

There were some differences in patterns across the two classes when we compared the sensitivity analysis with the main model estimated probabilities and means. Most of the indicators showed no significant differences across the classes in either model with confidence intervals overlapping in both models. However, parity and maternal weight did not vary across the classes in the sensitivity analysis but did in the main analysis, whilst the mean AFB now differed significantly between the two classes. A comparison of the response profiles for the full and restricted samples is shown in Table C.3. Whilst the sensitivity analyses models had better model fit and greater class separation (see Table C.2), the substantive conclusions do not change, with White British mothers showing more trait clustering than Pakistani-origin mothers, but neither ethnic group showing definitive clustering of all traits, and so we chose to use the main latent class analysis models in our regression models.

C.2.3 Supplementary analyses building up strategies by groups of traits

As another way to explore trait clustering, we checked how restricting which groups of life history traits were included in two class models affected goodness of fit and entropy statistics for each of our four samples. The results of this analysis are shown in Table C.4.

Building up models by groups of life history traits showed that models containing just postnatal parental investment indicators fit the data the best, with low AIC and BIC values and good class separation across the four samples. Models started to fit less well once other trait groups were added, with the models with all trait groups included having the highest AIC and BIC values in all four samples, indicating that the most complex model was the worst fit to the data.

The entropy statistics show broadly similar patterns across both BiB samples and the MCS White UK sample. The simplest model (Model 1 with just postnatal investment indicators) had the greatest class separation whilst Model 3 (postnatal and prenatal investment plus reproductive timing/effort indicators) had the lowest degree of class separation for three of the four samples. The MCS Pakistani-origin mothers showed a different pattern, with Model 5 (i.e. the model with all indicators included) having the lowest degree of class separation.

The changes in the entropy statistics across the model progression suggest that including more traits aids class separation to some extent, but that the degree to which people cluster into groups is driven more strongly by some trait groupings than others. For example, the addition of reproductive timing/effort indicators reduced the degree of class separation in all four samples (particularly so in the BiB Pakistani sample), suggesting that this aspect of life history may not cluster well with parental investment. In contrast, for three of the four samples the addition of mating effort indicators and somatic investment indicators increased the degree of class separation, suggesting that there is clustering of traits across different domains. This suggests that these variables are important for distinguishing life history strategies and that we should see class differences in mating effort and somatic investment indicators in the models with all trait groupings included. We do indeed see significant differences in the predicted direction in the estimated probabilities of no longer living with the child's father and health indicators in the two White samples, whilst bodyweight appears to be driving the class separation in the BiB Pakistani-origin mothers sample Table 4.6). However, not all the somatic investment indicators help to separate the classes in the predicted direction, with for example "slow" mothers being significantly more likely to drink alcohol in three of the four samples. We must interpret the MCS Pakistani-origin statistics with caution due to the small sample sizes and the necessary exclusion of the vaccination variable due to low cell counts. But with that caveat, the entropy changes in the model progression in this sample (and related indicator patterns in Table 4.4) suggest that somatic investment indicators are not so helpful in separating out these women into life history strategies.

Table C.1: Coding of life history traits

Life history domain	Indicator (variable name)	MCS Variables	BiB variables	MCS Coding	BiB Coding
Parenting	Breastfeeding initiation (everbf)	ambfeva0 “S1 MAIN Ever tried to breastfeed C1”; ambfeda0 “S1 MAIN Age when last had breast milk C1” (in days); ambfewa0 “S1 MAIN Age when last had breast milk C1” (in weeks); ambfema0 “S1 MAIN Age when last had breast milk C1” (in months); bmbfeaa0 “S2 MAIN Age child last had breast milk (text) C1”; bmbfmta0 “S2 MAIN Age child last had breast milk (months) C1”	BreastFed “Whether Read code recording as have been breastfed”; mede8 “Child ever breastfed”; bib36c1 “Was child ever breastfed”; bib36c2 “Is child still being breastfed”; all24c1 “Child currently breastfed”; all24c2 “If not currently breastfed”; bib24f1 “Was child ever breastfed”; bib24f2 “Is child still being breastfed”; all12c1 “Child ever breastfed”; all12c2 “ Child still breastfed”; all12c3 “How old when child stopped breastfeeding”; bib12e1 “Was child ever breastfed”; bib12e2 “Is child still being breastfed” ; bib6c1 “Was child ever breastfed”; bib6c2 “Is child still breastfed”.	Coded 0 – ‘No’ if answer recorded as ‘No’ or ‘N/A’ in all answered breastfeeding questions. Coded 1 – ‘Yes’ if answer recorded as ‘Yes’ or ‘Still having breastmilk’ to at least one of the breastfeeding questions. Coded . – ‘Missing’ if no breastfeeding questions asked or answered or marked or all marked ‘Refusal’, ‘Don’t know’ or ‘N/A’.	
	Breastfeeding duration in months (bfd)	ambfema0 “S1 MAIN Age when last had breast milk C1” (in months); ambfewa0 “S1 MAIN Age when last had breast milk C1” (in weeks); ambfeaa0 “S1 MAIN Age when last had breast milk C1” (text); ambfeda0 “S1 MAIN Age when last had breast milk C1” (in days); bmbfmta0 “S2 MAIN Age child last had breast milk (months) C1”; bmbfeaa0 “S2 MAIN Age child last had breast milk (text) C1”.	mede8wk “Breastfeeding duration in weeks”; all24c2wk “Breastfeeding duration in weeks”; all12c3wk “Breastfeeding duration in weeks”; mede8dy “Breastfeeding duration in days”; all24c2dy “Breastfeeding duration in days”; bib24bfdays “Age stopped breastfeeding (days)”; all12c3dy “Breastfeeding duration in days”; bib12bfdays “Age stopped breastfeeding (days)”; bib6bfdays “Age stopped breastfeeding (days)(derived)”	Converted answers given in days or weeks to months. Assigned duration of half a day (0.01642744 months) when child was ‘Less than one day’ old when last had breast milk. Used largest value of all answers given. Assigned duration of 2 weeks (0.5 months) if bmbfmta0 response marked as ‘0’. Interview date and baby’s birth date used to determine duration for those who responded ‘Still breastfeeding’ (MCS). Used baby’s age for mothers still breastfeeding at time of last survey and where mothers stopped breastfeeding between surveys, duration was coded as the age of the child in the last survey where breastfeeding was recorded as still happening (BiB). ‘Don’t know’, and everbf=0 coded as . -‘Missing’.	
	Vaccinations (vaxcat)	amimana0 “S1 MAIN Had any immunisations C1“; amimmua0 “S1 MAIN Has all immunisations C1”; amimrba0 “S1 MAIN Immunisations info from Red	all12n1dtp2rbk “dpt2 imm checked red book”; all12n1dtp3rbk “DTP3 imm checked red book”; all12n1dtp4rbk “DTP4 imm checked red book”; all12n1hbrbk “hb	Mothers who were only productive in Wave 1 were coded 0 “None” if they answered “No” to their child having any immunisations and 1 “Some” if	Created variables for each routine immunisation, with only those immunisations verified by checking in the

		Book? C1”; bmpobma0c “S2 MAIN How many doses of vaccine for polio by mouth C1. Corrected; bmdipha0c “S2 MAIN How many doses of vaccine for diphtheria C1. Corrected”; bmtetaa0c “S2 MAIN How many doses of vaccine for tetanus C1. Corrected”; bmwhcoa0c “S2 MAIN How many doses of vaccine for whooping cough C1. Corrected”; bmrbcoa0c “S2 MAIN Redbook consulted C1. Corrected”; amimrba0 “S1 MAIN Immunisations info from Red Book? C1”	imm checked red book”; all12n1men12rbk “Men12 imm checked red book”; all12n1men3rbk “Men3 imm checked red book”; all12n1menc4rbk “Men4 imm checked red book”; all12n1mmr13rbk “mmr13 imm checked red book”; all12n1othrbk “Other imm checked red book”; all12n1pcv13rbk “pcv13 imm checked red book”; all12n1pcv2rbk “pcv imm checked red book”; all12n1pcv4rbk “pcv4 imm checked red book”; all12n1tbrbk “tb imm checked red book”; all24m1mm2rbk “MMR2 imm checked red book”; all24m1mrbk “mmr1 imm checked red book” ; all24m1pcvrbk “PCV imm checked red book”	they answered “Yes” and the red book confirmed this. They were coded 2 “All” if they answered “Yes” to the child having all immunisations and this was confirmed by the red book. Wave 2 included questions about specific vaccines and for women who were productive in this wave we coded 0 “None” if all of the vaccinations were recorded as not having been given or not verified by the red book, we coded 1 “Some” if at least one of the individual vaccines was given and verified, and 2 “All” if all of the separate vaccinations were given and verified. Answers that were not verified by the red book were coded as missing.	red book coded as having been given, and then summed these to give a count of the number of routine vaccinations given out of a max of 10. Vaccines coded as given if recorded as ‘No’ at 12months but ‘Yes’ at 24 months. Count converted to ordered categorical variable with no vaccinations given coded as 0 “None”, “1-9” vaccinations given coded as 1 and “All 10” coded as 2.
	Reading to child (read)	bmofrea0c “S2 MAIN How often do you read to the child C1. Corrected”	bib36i1fhowoften “How often spent reading/being read to”; bib24l1fhowoften “How often spent reading/being read to”	Coded 2 “Everyday” and 1 “Several times a week” if these answers were given, or 0 “Once or twice a week or less” if answered “Once or twice a week”, “Once or twice a month”, “Less often” or “Not at all”.	Used answer at last productive survey wave in which reading question was asked. Coded 2 if 5-7 days per week, 1 if 2-4 days per week, 0 if once a week or less.
	Taking child to activities (activities)		all12h1 “Baby activities first 6 mo”; all12h2 “Baby activities 6 mo onwards”; all24h1 “Child activities from 12mo”		Original variables coded as 1 “Rarely”, 2 “At least once a month”, 3 “Usually once a week”, 4 “More than once a week”. We summed across and divided by the number of answers given for each woman to give an average activities score. This was then simplified into a binary variable “Takes child to activities regularly” coded 1

					"Yes" if score >=1.5 and coded 0 "No" if score <1.5.
	Affection (affection)	bmpiawa0c "S2 MAIN Warm, affectionate relationship with child C1. Corrected"	bib6p6 " How often do you express affection by hugging etc. child"; bib6p9 "How often do you have warm/close times with child"; bib6p7 "How often do you hug child for no particular reason"; bib6p8 " How often do you tell child how happy he makes you"; bib24o6 "How often express affection for child"; bib24o9 "How often have warm times with child"; bib24o7 "How often hug or hold child"; bib24o8 "How often tell child he makes you happy"	Original variable coded as 1 "Definitely does not apply", 2 "Not really" 3 "Neutral, not sure", 4 "Applies sometimes", 5 "Definitely applies" and 6 "Can't say". We coded answers 1-4 as 0 "No", and 5 as 1 "Yes". 6 "Can't say" was coded as missing.	Original variables coded as 1 "Never", 2 "Rarely", 3 "Sometimes", 4 "Often", 5 "Always/almost always". We summed across and divided by the number of answers given for each woman to give an average affection score. This was then simplified into a binary variable, "Expresses affection towards child regularly", coded 0 "No" if affection score was less than 4 and 1 "Yes" if affection score was 4 or higher.
	Birthweight and gestational age (bwgst)	ADGESTA0 "S1 DV Cohort Member Gestation time in days (estimated) C1"; ambiwta0 "S1 MAIN Birth weight (unit) C1"; amwtkga0 "S1 MAIN Birth weight (kilo) C1"; amwtoua0 "S1 MAIN Birth weight (ounce) C1"; amwtlba0 "S1 MAIN Birth weight (pound) C1"; bnwtkga0 "S2 MAIN Birthweight kilos and grammes C1"; bnwtlba0 "S2 MAIN Birthweight pounds C1"; bnwtoua0 "S2 MAIN Birthweight ounces C1"	eclbirthwt "Birth weight (g)" (eClipse); eclgestwks "Gestation to last completed week"	Coded . as missing if birthweight>9kgs or <0kgs or if both birthweight and gestational age information missing. Coded 0 "LBW and/or premature" if birth weight<2.5kg and/or gestational age <37 weeks. Coded 1 "Normal weight and term" if birthweight >=2.5kgs and gestational age >=37 weeks (NB: "normal weight" here also includes heavy babies, as although they have elevated risks for some health problems, their size is indicative of greater PI). MCS weights converted from pounds and ounces where applicable and BiB weights from grams to kgs.	
Reproduction	Age at menarche (menarche)		rep0firper "Age at first period"		Only available in whole years so coded in years
	Age at cohabitation or marriage (acm)	ammayr00 "S1 MAIN Year got married"; ammamt00 "S1 MAIN Month got married"; bmmayr00 "S2 MAIN Year got married"; bmmamt00 "S2 MAIN Month got married"; amliyr00		Age at marriage and age at cohabitation both derived from date of birth and month and year of event and the younger age of the two used to create continuous "Age at	

		"S1 MAIN Year started living together"; amlimt00 "S1 MAIN Month started living together"; bmliyr00 "S2 MAIN Year started living together"; bmlimt00 "S2 MAIN Month started living together"; ampdby00 "S1 MAIN Date of Birth (year)"; ampdbm00 "S1 MAIN Date of Birth (month)"; bmpdby00 "S2 MAIN Person Date of Birth (year)"; bmpdbm00 "S2 MAIN Person Date of Birth (month)"		cohabitation or marriage" variable. NB: refers to marriage or cohabitation with baby's father, but may not be the age at which women first married or cohabited.	
	Age at first birth (afb)	AMDAGB00 "S1 MAIN Respondent age at birth of CM"; BMDAGB00 "S2 MAIN DV Respondent age at birth of CM"	admincdobagemy "Mother age at child date of birth (years)"	New afb variable coded as missing for mothers for whom CM is not first child (i.e parity>0) and/or age at birth "Not known" or "Not applicable". Wave 1 variable used for those who entered in Wave 1 and Wave 2 for those who entered in Wave 2.	New afb variable coded as missing for mothers for whom CM is not first child (i.e parity>0)
	Parity 4+ (parcat)	ADOTHS00 "S1 DV Number of siblings of CM in household"; BDOTHS00 "S2 DV Number of siblings of CM in household"	eclregpart "Registerable parity"	Used as proxy for parity. Converted to categorical to combine low numbers: 0 "None, or 1 or 2 other children", 1 "3+ other children"	Converted to categorical to combine low numbers: 0 "None, or 1 or 2 other children", 1 "3+ other children"

	Relationship stability with baby's father (rels)	ADFINH00 "S1 DV Natural father in HH"; BDCHNF00 "S2 DV Change in Natural father status"; BDRELP00 "S2 DV Relationship between Parents/Carers in Household"; BDFINH00 "S2 DV Natural father in HH"; bnrelp00 "S2 MAIN Relationship with child's father/mother at birth"	medg3 "Cohabitation status"; all24d2 "Cohabitation status"; all12d2 "Cohabitation status"; bib12b02 "Living arrangements"; bib6e02 "Living arrangements"; hhd0cohabt "Cohabitation status"	Used answer at last productive survey wave in which cohabitation question was asked. Assigned 0 "Living with baby's father" if marked as father "In household at both sweeps" or "In household at MCS2, not MCS1" or if marked "Resident in household" at Wave 1 and the household was unproductive at Wave 2. Assigned 1 "Not living with baby's father" if father "In household at MCS1, not MCS2", "Not in household at either sweep" or if marked "Not resident in household" at Wave 1 and the household was unproductive at Wave 2. Coded as missing if father marked as deceased in either wave.	Used answer at last productive survey wave in which cohabitation question was asked. Assigned 0 - "Living with baby's father" if mother answered "Living with baby's father" or "Living with child's other parent". Assigned 1 – "Not living with baby's father" if mother answered "Living with another partner", "Not living with a partner", "Not living with partner but in relationship", or "Not living with a partner and not in relationship". Coded as missing if productive in last survey wave but did not answer question.
Health	Health status (health; ghq_75)	amgehe00 "S1 MAIN General Health"; bmgehe00 "S2 MAIN General health";	ghq0ques01 - ghq0ques028 (GHQ-28 items)	Original variables coded as 1 "Excellent", 2 "Good", 3 "Fair" and 4 "Poor". Largest value (i.e. worse health) of the two answers used to make new variable.	75th centiles were calculated within ethno-language group (as per Prady et al., 2015) to minimise variation caused by potential measurement inconsistencies. Where language was missing we assumed English. This left just three mothers not assigned to an ethno-language category. Coded 0 if <75th centile and 1 if ≥75th centile. Being in 75th centile or above is indicative of caseness and therefore poorer mental health.

	Bodyweight (mwtkg)	amwtbf00 "S1 MAIN Weight before pregnancy" (units); amwbkg00 "S1 MAIN Weight before pregnancy" (kgs); amwbst00 "S1 MAIN Weight before pregnancy" (stones); amwblb00 "S1 MAIN Weight before pregnancy" (pounds)	Bkfmumbkwt "Mother's weight at booking (kgs)" (at ~12 weeks gestation)	Weights converted from pounds and stones where applicable. Kept as continuous variable.	Kept as continuous variable.
	Ever regularly smoked (regsmk)	amsmev00 "S1 MAIN Ever smoked"; bmsmev00c "S2 MAIN Ever regularly smoked tobacco products. Corrected"	smk0regsmk "Mother ever regularly smoked"	Coded 0 "No" if answered "No" (to both questions if productive in both waves) and 1 "Yes" if answered "Yes" to either question. Coded missing if marked "Not applicable".	Coded 0 "No" if answered "No" and 1 "Yes" if answered "Yes, more than 1 years", "Yes, less than 1 year" or "Yes, not specified".
	Drinks alcohol (alco)	amaldr00 "S1 MAIN Frequency of current alcohol consumption"; amdrof00 "S1 MAIN Frequency of alcohol consumption before preg"; bmaldr00 "S2 MAIN How often usually drink alcohol"	alc0drpreg "Mother drank alcohol during pregnancy or 3 months before"	Coded 0 "No" if answered "Never" to all productive questions, coded missing if all answers marked "Refusal" or "Don't know" or "Not applicable", all other frequencies coded 1 "Yes".	Coded 0 "No" if answered "No" and 1 "Yes" if answered "Yes". Coded missing if answered "Don't remember".

MCS variables prefixed with a and b and labels prefixed with S1 and S2 relate to Wave 1 and Wave 2, respectively. MCS variables suffixed with c (and labels suffixed with Corrected) are variables that were mislabelled and were therefore corrected based on the survey questionnaire documentation. BiB variables prefixed with bib, all, or med, relate to BiB 1000, ALL IN and MeDALL sub-cohorts, respectively.

Table C.2: Sensitivity analysis for BiB: statistical criteria for models with two latent classes using full samples and restricted to mothers in at least one sub-cohort

	BiB: White British mothers						BiB: Pakistani-origin mothers					
Sample	n	AIC	BIC	Entropy	Fast class	Slow class	n	AIC	BIC	Entropy	Fast class	Slow class
All mothers	3,937	95745.17	96015.13	0.459	51%	49%	4,351	94694.33	94885.67	0.431	52%	48%
Sub-cohort mothers only	1,276	37086.90	37267.20	0.547	52%	48%	1,804	46695.40	46827.35	0.457	53%	47%

Models are adjusted for clustering at ward level, allow for continuous indicators to correlate and do no not constrain parameters to be equal across classes. All life history indicators included.

Table C.3: BiB sensitivity analysis: comparison of response profiles

	All mothers				Sub-cohort mothers only			
	White British mothers (n=3,937) Entropy=0.459		Pakistani-origin mothers (n=4,351) Entropy=0.431		White British mothers (n=3,937) Entropy=0.459		Pakistani-origin mothers (n=4,351) Entropy=0.431	
	Fast (51%)	Slow (49%)	Fast (52%)	Slow (48%)	Fast (52%)	Slow (48%)	Fast (53%)	Slow (47%)
Parenting								
Breastfeeding initiation	**0.21**	0.63	***0.55***	0.59	**0.45**	0.95	***0.80***	0.88
Breastfeeding duration (months)	**0.76**	11.17	**2.62**	13.88	**0.79**	12.11	**2.34**	15.15
Takes child to activities regularly	**0.49**	0.76	0.49	***0.48***	**0.53**	0.78	***0.46***	0.50
Expresses affection towards child regularly	***0.93***	0.95	0.88	***0.84***	***0.93***	0.96	0.88	***0.84***
Reads to child:								
Not very often	0.79	***0.84***	***0.65***	0.58	0.80	***0.83***	0.61	***0.63***
Quite often	**0.13**	0.05	***0.26***	0.24	***0.11***	0.05	***0.29***	0.21
Very often	**0.09**	0.11	***0.08***	0.18	***0.09***	0.12	***0.10***	0.16
Routine vaccinations given to child:								
None	**0.18**	0.09	0.08	***0.12***	***0.16***	0.09	0.10	***0.11***
Some	***0.59***	0.63	0.62	***0.58***	***0.59***	0.63	0.63	***0.58***
All	***0.24***	0.28	***0.29***	0.30	***0.25***	0.28	***0.28***	0.32
Child born normal birthweight and at term	***0.92***	0.93	***0.88***	0.91	***0.92***	0.92	***0.88***	0.91
Reproduction								
Age at menarche (years)	***13.03***	13.05	13.59	**13.27**	***12.98***	13.07	13.51	***13.43***
Age at first birth (years)	**21.02**	28.88	***24.82***	24.93	**22.73**	28.81	**23.35**	26.74
Parity 4+	**0.12**	0.08	0.16	**0.33**	***0.10***	0.09	***0.25***	0.24
No longer living with child's father	**0.47**	0.13	***0.08***	0.06	**0.39**	0.18	***0.07***	0.06
Health								
Poor mental health	**0.31**	0.23	0.29	***0.33***	**0.32**	0.23	0.30	***0.34***
Ever smoked regularly	**0.69**	0.47	***0.09***	0.08	**0.64**	0.48	***0.09***	0.05
Drinks alcohol	0.63	**0.75**	***0.01***	0.00	0.67	***0.74***	***0.00***	0.00
Bodyweight (kgs)	72.58	***71.20***	**59.71**	71.20	73.48	***71.94***	66.22	***63.37***

Estimated probabilities for categorical indicators and estimated means for continuous indicators; continuous indicators are those with units in brackets. "Faster" values for each trait highlighted in bold for each sample and italicised where confidence intervals overlapped with the other class in the sample.

Table C.4: Supplementary analysis: building up models by trait groupings: model fit and class separation statistics

		MCS						BiB					
		White UK-born mothers (n=14,840)			Pakistani-origin mothers [a] (n=931)			White British mothers (n=3,937)			Pakistani-origin mothers (n=4,351)		
	Model	AIC	BIC	Entropy	AIC	BIC	Entropy	AIC	BIC	Entropy	AIC	BIC	Entropy
1	Postnatal PI only	**94828.41**	**94950.10**	**0.710** [b]	**2838.19**	**2901.06**	**0.681**	**13872.80**	**13991.69**	**0.711**	**19680.00**	**19801.03**	**0.683**
2	1 + prenatal PI	104052.95	104189.84	**0.710** [b]	3262.40	3334.94	**0.681**	16001.14	16132.98	0.698	22634.36	22768.31	0.669
3	2 + repro timing	232473.44	232739.62	0.605	7378.63	7528.56	0.611	45308.97	45541.26	0.428	51262.54	51453.89	0.249
4	3 + mating effort	246972.15	247253.54	0.611	7729.83	7889.42	0.616	49806.55	50051.40	0.435	53442.82	53634.17	0.257
5	4 + somatic effort	418201.05	418634.54	0.627	12825.62	13081.94	0.609	95745.17	96015.13	0.459	94676.42	94874.14	0.388

PI=parental investment; repro=reproductive timing. These models are adjusted for clustering at ward level, allow for continuous indicators to correlate and do not constrain parameters to be equal across classes. MCS models are additionally adjusted for sampling weights (but not stratification as GOF stats are not estimable after svyset). Ns are unweighted. [a] Vaccination variable omitted from the MCS Pakistani-origin models due to small cell sizes. [b] Breastfeeding initiation constrained to +15 for Class 2 due to logit intercept being close to +/-15. Best fit and class separation statistics highlighted in bold for each sample. AIC=Akaike Information Criterion; BIC=Bayesian Information Criterion.

Table C.5: Correlations between socioeconomic and environmental indicators (MCS)

	Socioeconomic disadvantage	Area-level deprivation	Subjective environmental harshness	Objective environmental harshness	Lived away from home before age 17	Parents separated when a child	Parental death
Socioeconomic disadvantage		0.452	0.228	0.359	0.032	0.102	0.013
Area-level deprivation	0.522		0.410	0.514	0.026	0.047	0.005
Subjective environmental harshness	0.418	0.502		0.458	0.114	0.153	0.046
Objective environmental harshness	**0.532**	0.499	0.484		0.025	0.030	-0.007
Lived away from home before age 17	0.285	0.230	0.243	0.243		**0.515**	0.116
Parents separated when a child	0.306	0.218	0.195	0.207	0.386		**-0.211**
Parental death	-0.002	0.004	-0.002	0.013	0.075	**-0.122**	

Strong correlation against predicted direction — *No correlation* — *Strong correlation in predicted direction*

Correlations between socioeconomic and environmental indicators in the MCS samples adjusted for clustering and sampling weights but not stratification (as fully adjusting for complex survey design is not possible with the polychoric command). Polychoric correlations calculated for combinations of binary and/or ordinal variables, polyserial correlations calculated for combinations of continuous and binary/ordinal variables, Pearson's correlations calculated for combinations of continuous variables. Correlations for White UK-born mothers are shown below the diagonal and correlations for Pakistani-origin mothers are shown above the diagonal. Blue cells represent correlations in the predicted direction whilst red cells highlight correlations which go against the predicted direction (the darker the shade, the stronger the correlation). Strongest correlations shown in bold for each sample

Table C.6: Correlations between socioeconomic and environmental indicators (BiB)

	Socioeconomic disadvantage	Area-level deprivation	Water chlorination	Air pollution	Passive cigarette smoke	Damp/mould in home	No central heating in home
Socioeconomic disadvantage		0.191	-0.005	0.108	0.075	0.069	-0.031
Area-level deprivation	0.358		-0.032	0.381	0.007	0.141	**0.433**
Water chlorination	0.102	0.082		-0.050	0.151	-0.038	0.019
Air pollution	0.086	0.177	0.019		0.000	0.132	0.178
Passive cigarette smoke	0.355	**0.364**	0.075	0.104		0.040	**-0.096**
Damp/mould in home	0.122	0.110	-0.032	**-0.068**	0.121		-0.071
No central heating in home	0.118	-0.018	0.133	0.065	0.178	-0.015	

Strong correlation against predicted direction | *No correlation* | *Strong correlation in predicted direction*

Correlations between socioeconomic and environmental indicators in the BiB samples adjusted for clustering. Polychoric correlations calculated for combinations of binary and/or ordinal variables, polyserial correlations calculated for combinations of continuous and binary/ordinal variables, Pearson's correlations calculated for combinations of continuous variables. Correlations for White British mothers are shown below the diagonal and correlations for Pakistani-origin mothers are shown above the diagonal. Blue cells represent correlations in the predicted direction whilst red cells highlight correlations which go against the predicted direction (the darker the shade, the stronger the correlation). Strongest correlations shown in bold for each sample.

Table C.7: Probability estimates of life history traits by sample and class: 3 class models

	MCS						BiB					
	White UK-born mothers (n=12,647) Entropy=0.587			**Pakistani-origin mothers (n=712)** Entropy=0.621			**White UK-born mothers (n=12,647)** Entropy=0.587			**Pakistani-origin mothers (n=712)** Entropy=0.621		
	Fast (33%)	Mid (22%)	Slow (45%)	Fast (44%)	Mid (29%)	Slow (27%)	Fast (31%)	Mid (34%)	Slow (36%)	Fast (43%)	Mid (38%)	Slow (19%)
Parenting												
Breastfeeding initiation	**0.45**	0.67	0.89	***0.69***	0.75	*0.90*	**0.19**	0.33	0.69	0.57	*0.58*	**0.53**
Breastfeeding duration (months)	**0.26**	1.34	4.30	**0.40**	*4.65*	2.80	**0.43**	2.43	13.13	**2.15**	13.51	*14.27*
Takes child to activities regularly							**0.51**	0.53	0.80	0.48	*0.53*	***0.40***
Expresses affection towards child regularly	0.94	***0.93***	0.98	*0.90*	***0.87***	0.88	**0.89**	*0.99*	0.93	*0.89*	0.87	***0.77***
Reads to child:												
Not very often	***0.30***	0.28	0.07	0.44	**0.50**	*0.39*	*0.73*	**0.88**	0.80	0.61	**0.70**	*0.49*
Quite often	***0.21***	0.20	0.16	0.19	*0.17*	**0.25**	**0.17**	0.06	*0.05*	0.31	0.13	**0.35**
Very often	***0.49***	0.51	0.77	*0.37*	**0.33**	0.35	0.10	***0.05***	*0.14*	***0.09***	0.16	*0.16*
Routine vaccinations given to child [a]:												
None	0.00	0.00	***0.00***				***0.18***	0.16	*0.07*	0.09	***0.12***	*0.08*
Some	1.00	1.00	***1.00***				***0.58***	0.62	*0.63*	0.63	***0.56***	*0.64*
All							0.24	***0.23***	*0.30*	***0.28***	*0.32*	0.28
Child born normal birthweight and at term	0.91	***0.88***	0.93	***0.82***	0.83	*0.88*	***0.90***	*0.94*	0.93	0.89	***0.89***	*0.92*
Reproduction												
Age at menarche (years)							*13.17*	**12.85**	13.09	*13.58*	13.39	***13.21***
Age at cohabitation/marriage (years)	**21.31**	25.19	*25.46*	20.42	***19.69***	23.56						
Age at first birth (years)	**22.38**	27.02	30.23	***22.04***	*24.53*	24.44	**19.79**	24.73	29.51	**22.89**	25.61	28.94
Parity 4+	0.06	**0.12**	*0.04*	0.19	***0.23***	*0.11*	0.08	**0.15**	*0.07*	0.23	0.12	**0.50**
No longer living with child's father	**0.35**	0.26	0.06	***0.11***	*0.08*	0.10	**0.56**	0.27	0.11	***0.08***	0.07	*0.05*

Health												
Poor mental health							0.27	***0.33***	0.20	0.31	*0.29*	***0.35***
General health:												
Excellent	0.13	**0.08**	0.29	*0.10*	***0.09***	0.10						
Good	*0.58*	**0.50**	0.57	0.52	***0.45***	*0.56*						
Fair	0.24	**0.34**	0.12	0.29	***0.39***	*0.24*						
Poor	0.05	**0.09**	0.02	0.09	*0.08*	***0.10***						
Ever smoked regularly	*0.18*	***0.26***	0.22	*0.00*	0.02	***0.02***	***0.71***	0.64	0.44	***0.10***	*0.07*	0.08
Drinks alcohol	0.92	0.88	**0.97**	0.03	*0.01*	***0.07***	*0.63*	0.66	**0.76**	***0.01***	0.00	*0.00*
Bodyweight (kgs)	**60.07**	72.98	62.59	***57.12***	*66.64*	59.96	**61.07**	84.49	69.35	65.31	**58.01**	79.63

Estimated probabilities for categorical indicators and estimated means for continuous indicators; continuous indicators are those with units in brackets. "Fastest" values for each trait highlighted in bold and "slowest" values for each trait underlined in each group and italicised where confidence intervals overlapped with at least one other class in the group. [a] Vaccinations excluded from MCS Pakistani-origin model due to small cell counts.

Figure C.1: Estimated probabilities and means for MCS White UK-born mothers: 2 class model (n=12,647)

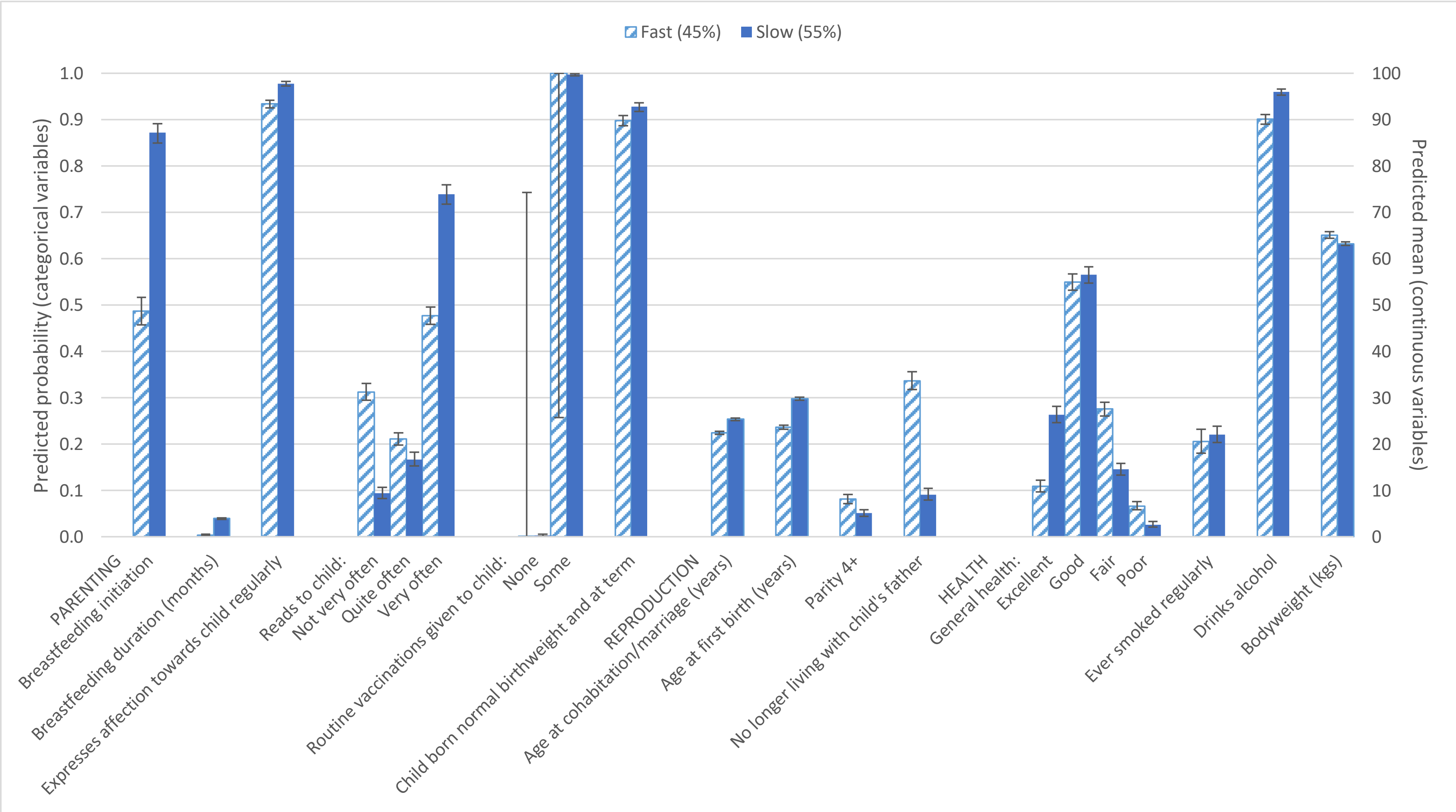


Figure C.2: Estimated probabilities and means for MCS Pakistani-origin mothers: 2 class model (n=712)

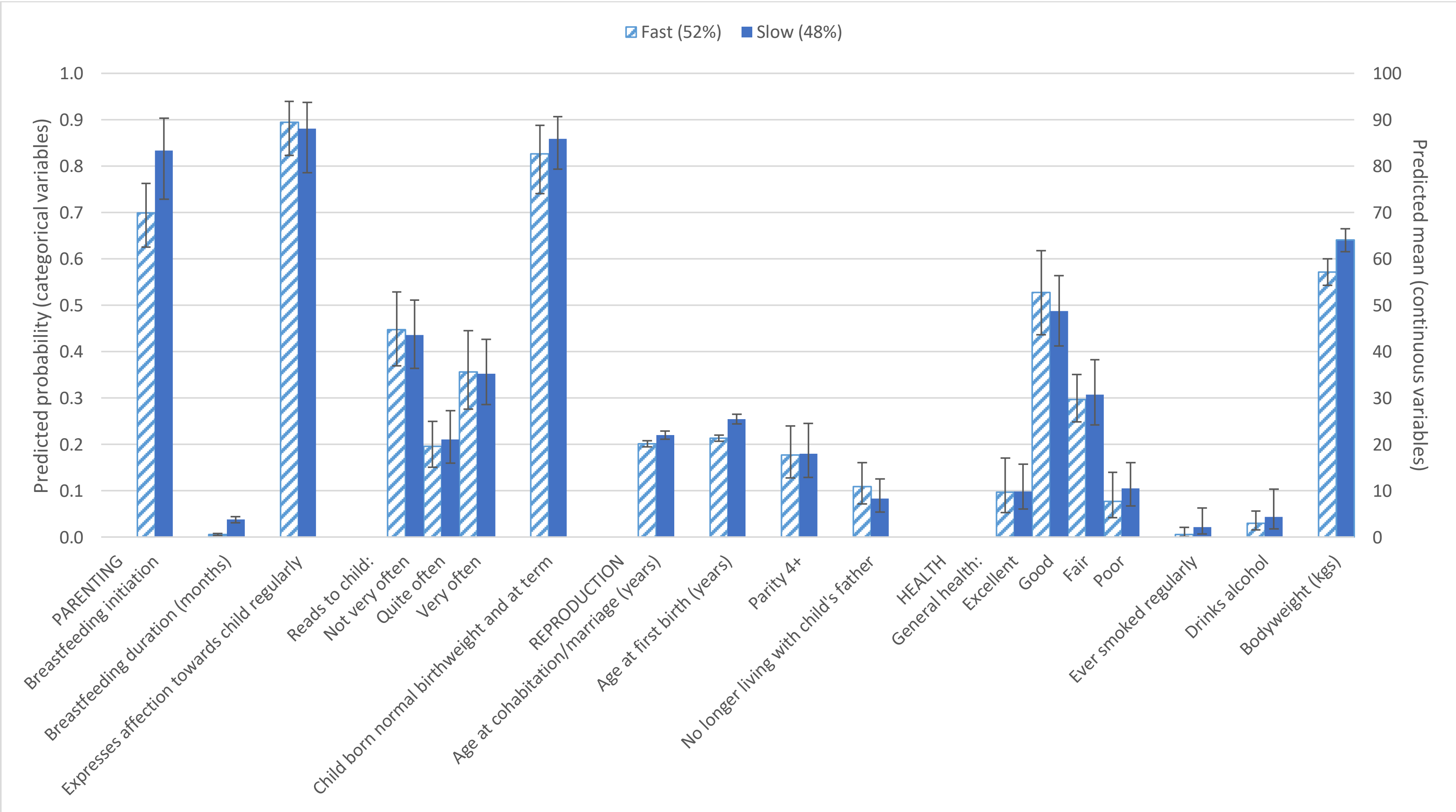


Figure C.3: Estimated probabilities and means for BiB White British mothers: 2 class model (n=3,937)

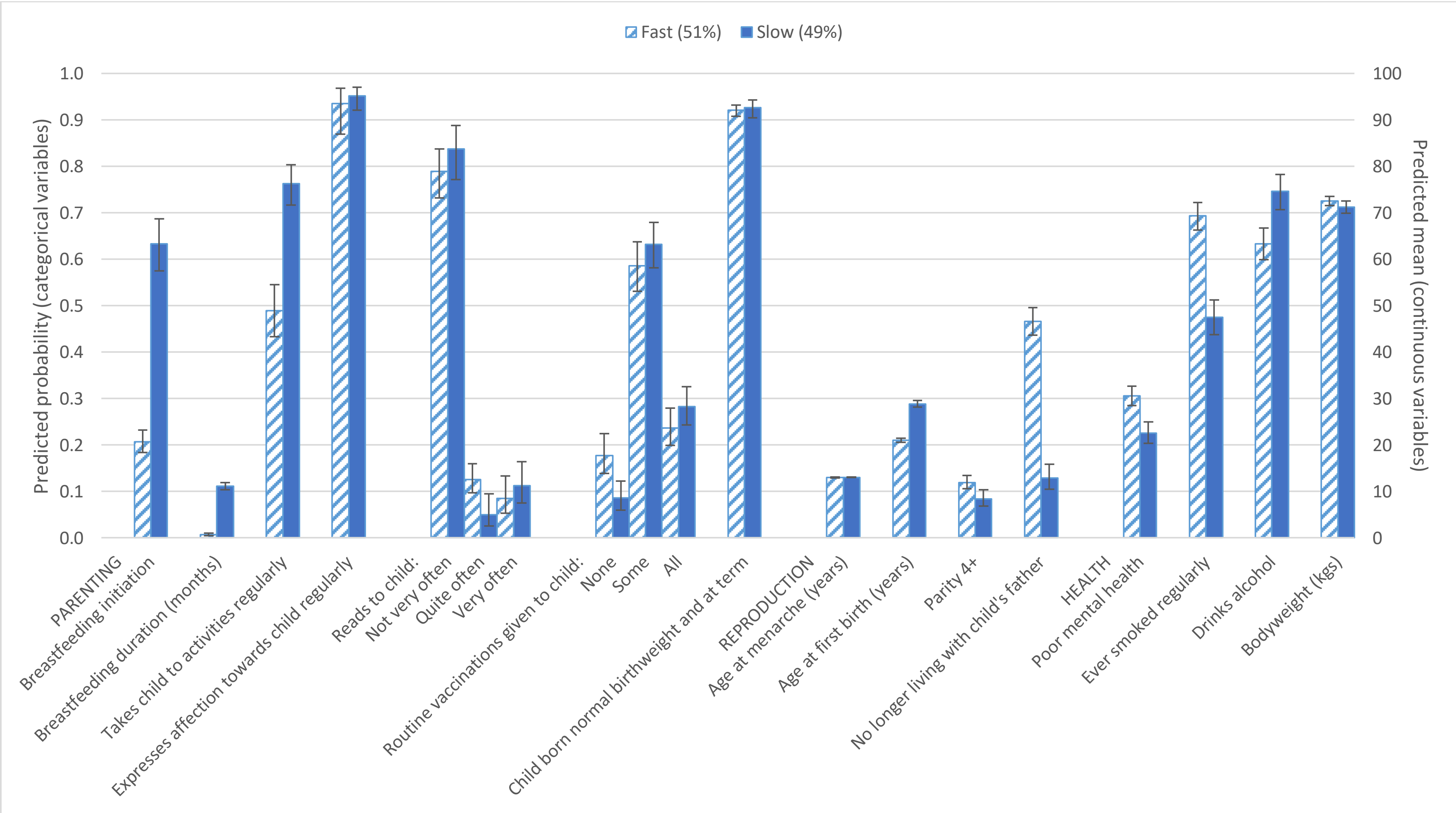


Figure C.4: Estimated probabilities and means for BiB Pakistani-origin mothers: 2 class model (n=4,351)

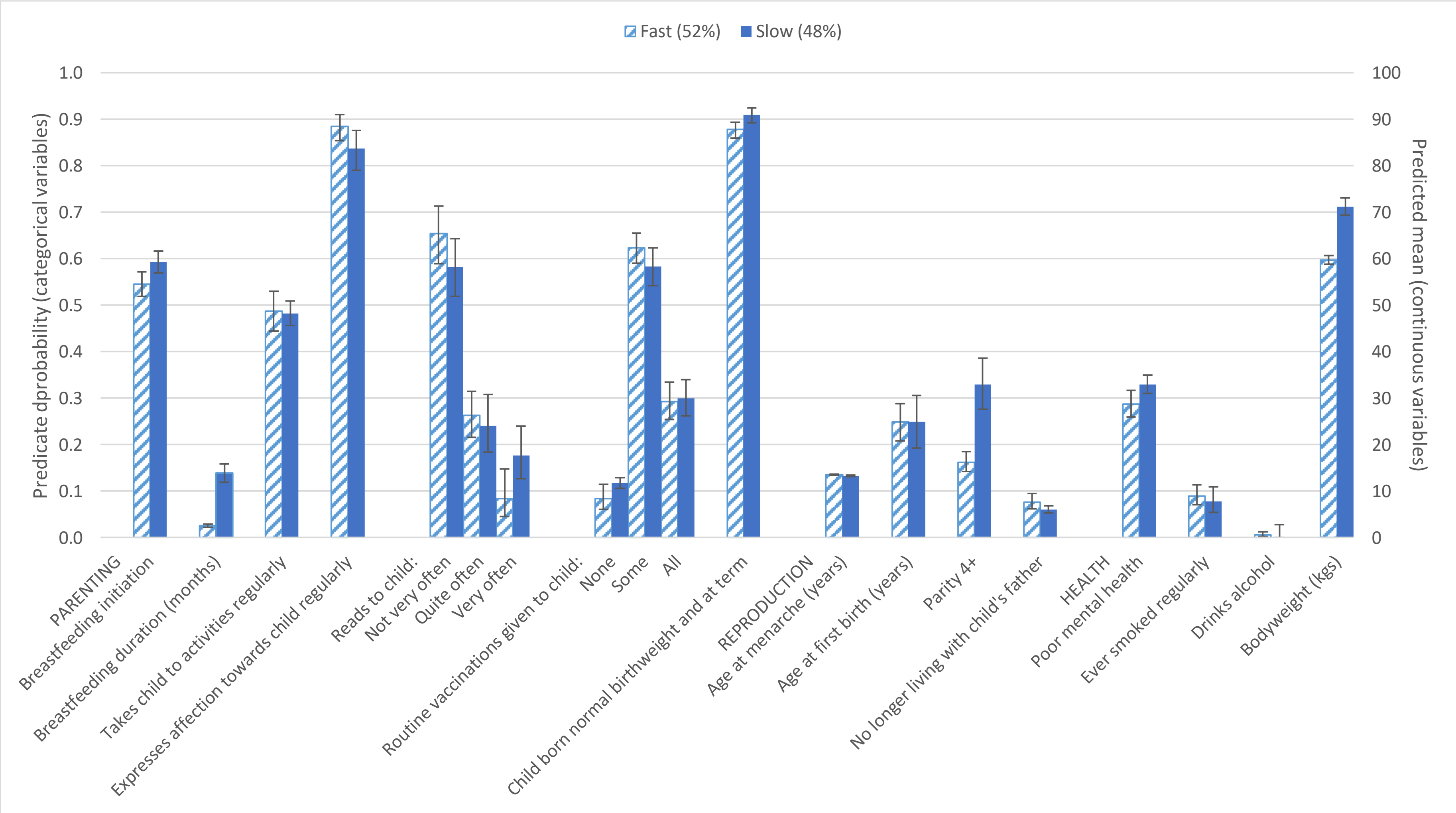


Figure C.5: Estimated probabilities and means for MCS White UK-born mothers: 3 class model (n=12,647)

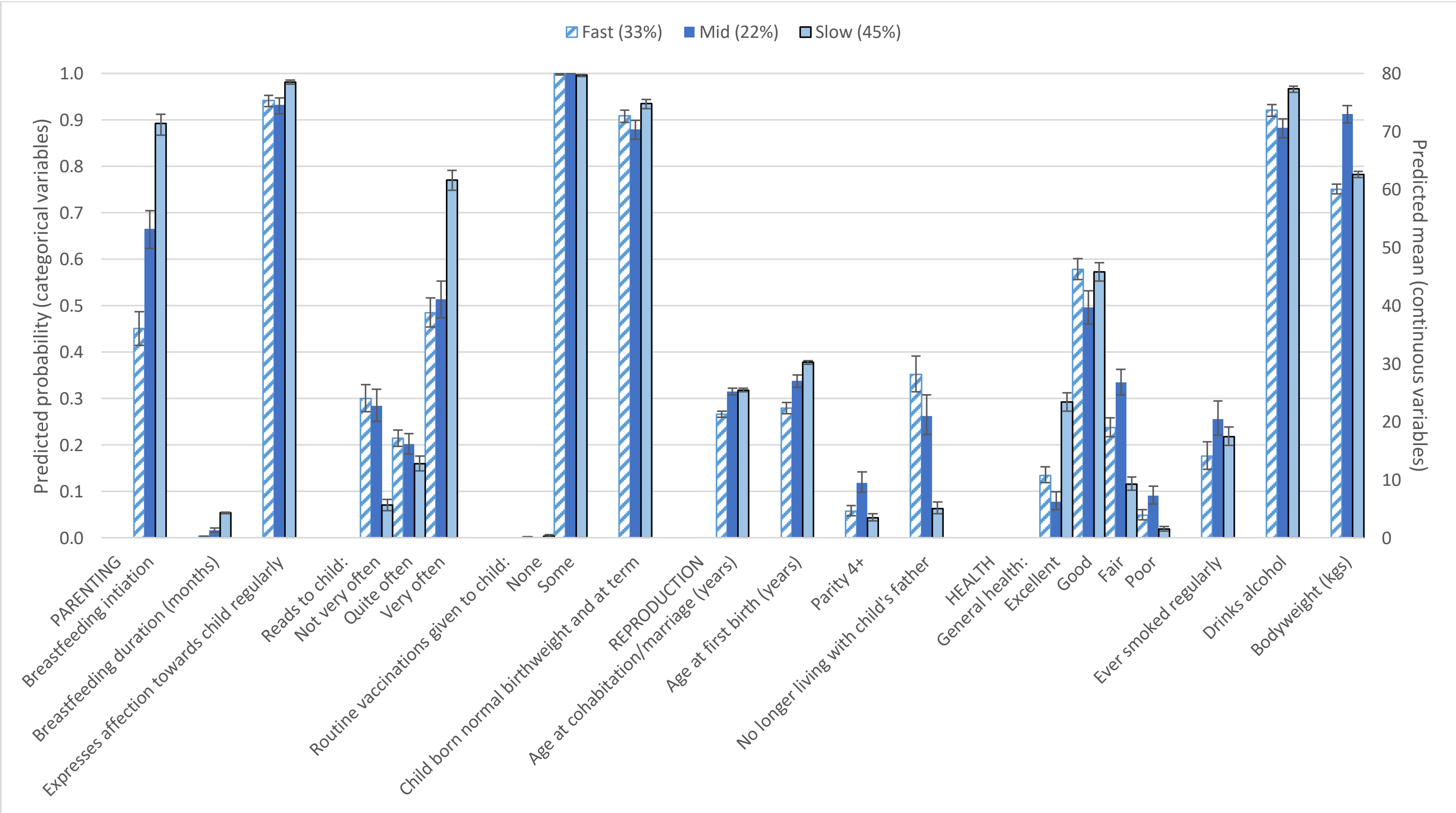


Figure C.6: Estimated probabilities and means for MCS Pakistani-origin mothers: 3 class model (n=712)

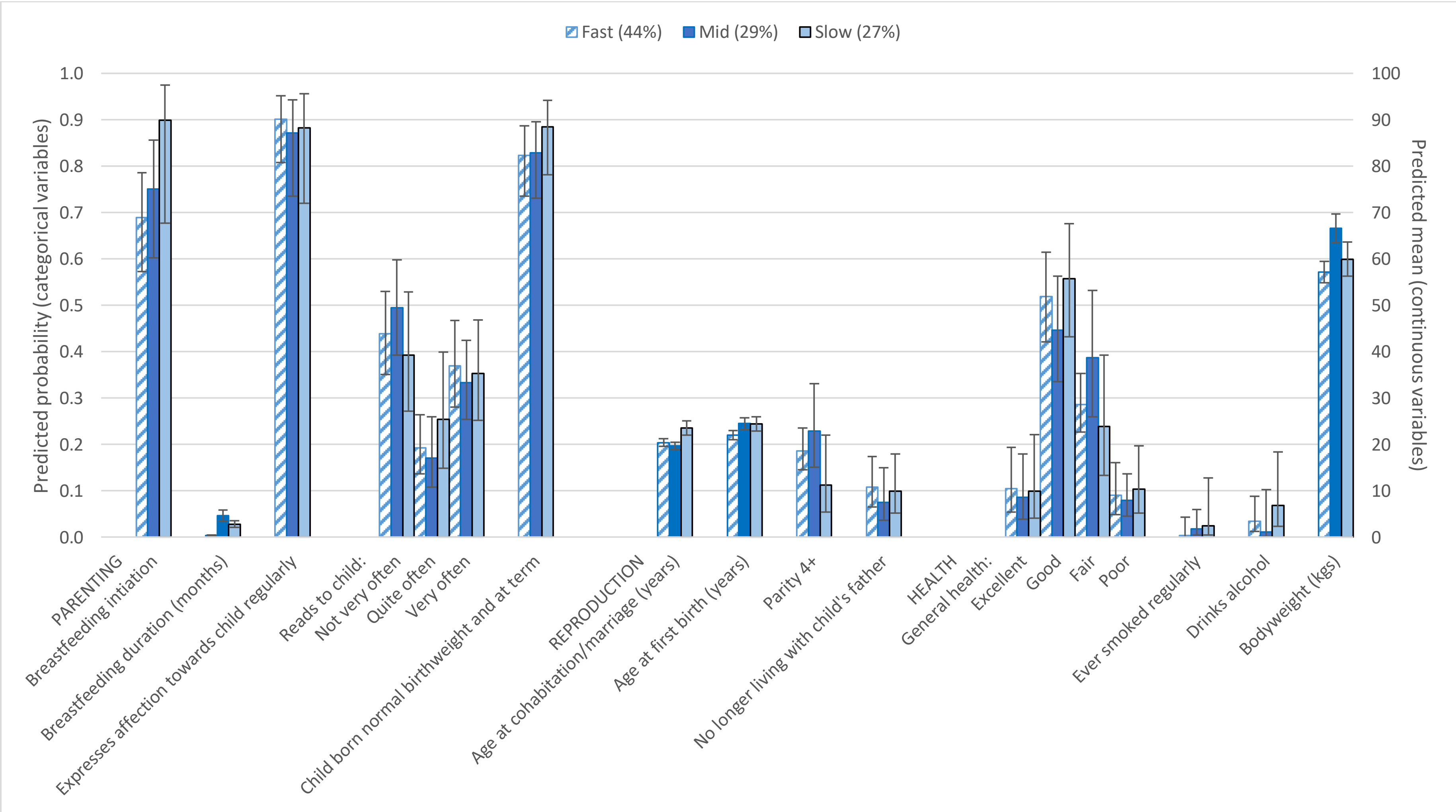


Figure C.7: Estimated probabilities and means for BiB White British mothers: 3 class model (n=3,937)

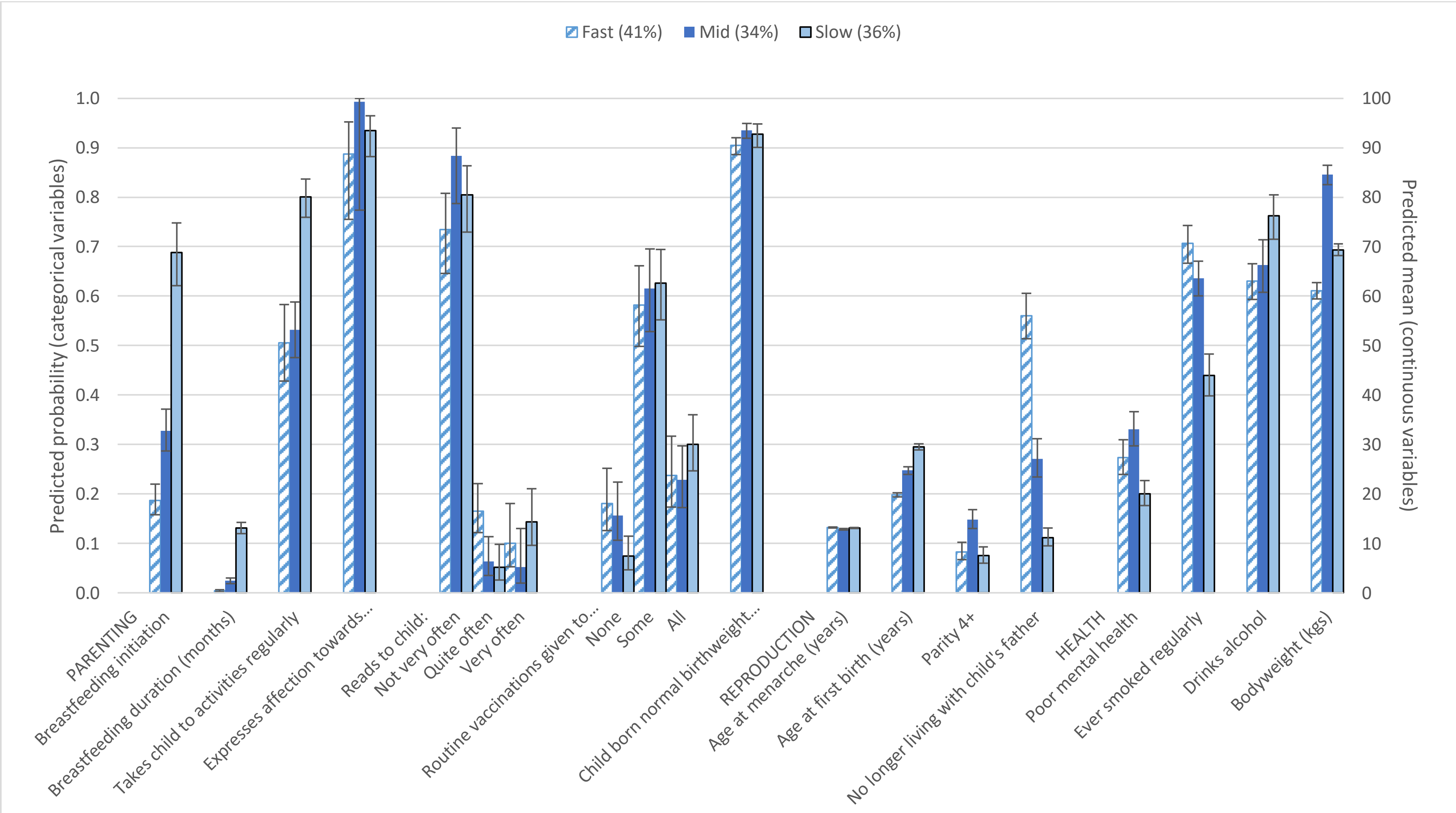
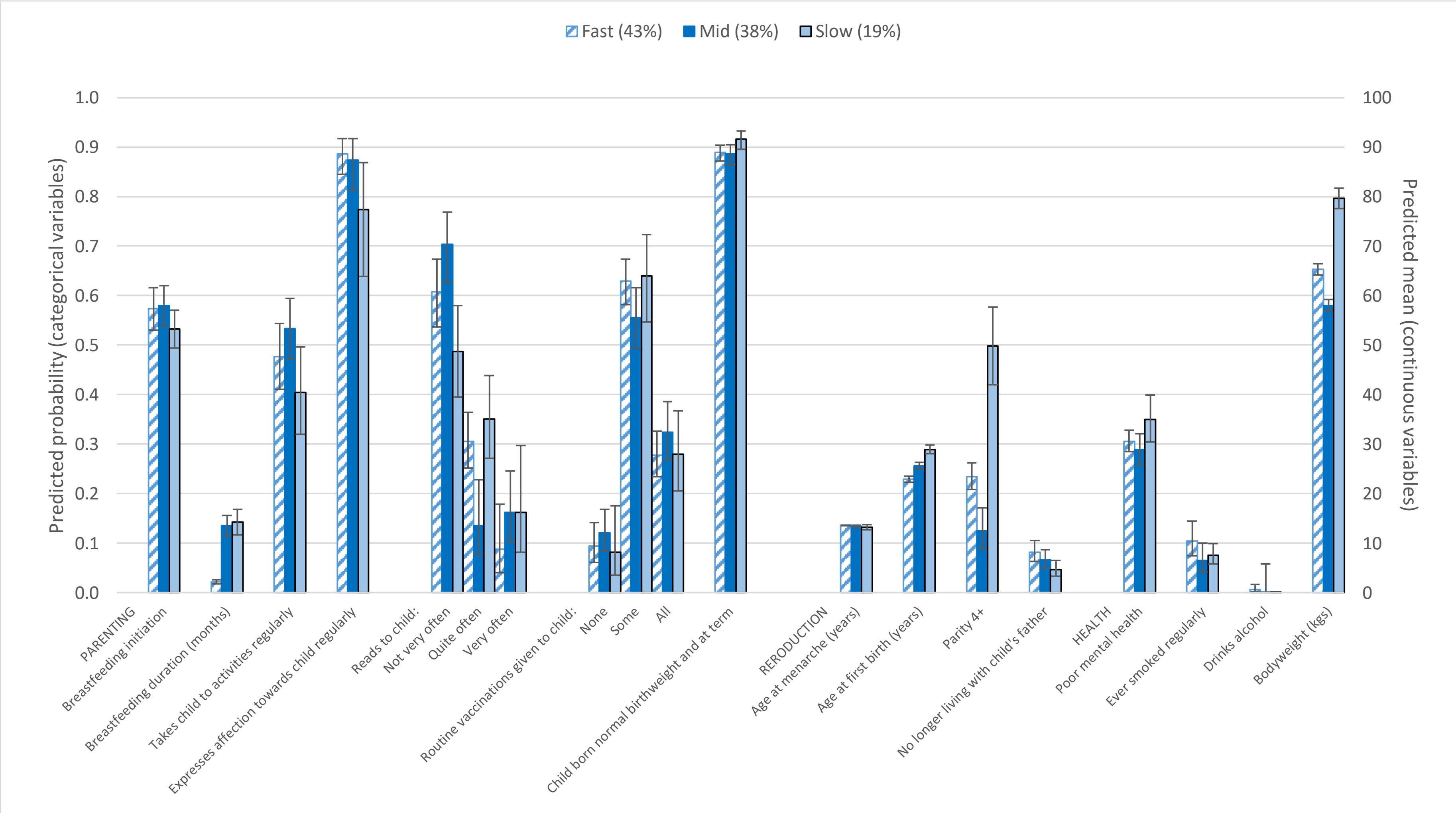


Figure C.8: Estimated probabilities and means for BiB Pakistani-origin mothers: 3 class model (n=4,351)



D. FORMATIVE EXPERIENCES

I have been involved in various projects throughout the duration of my PhD which have both broadened my knowledge and improved my skills as a researcher, and influenced the work I have produced. I will now briefly outline how my time at Public Health England, research at LSE, teaching at King's, sexual health outreach work, and fieldwork experience have all contributed to my academic development.

I started working with Public Health England's Behavioural Insights (PHEBI) Team through a Research Councils UK policy internship scheme in January 2017 and then extended my internship part-time before going on to secure a contracted position from January to June 2018. With a working knowledge of different behavioural frameworks (e.g. COM-B and the behaviour change wheel (Susan Michie, van Stralen, & West, 2011), the Theoretical Domains Framework (TDF) (Atkins et al., 2017; S Michie et al., 2005) and Behaviour Change Techniques (BCTs) (Susan Michie, Abraham, et al., 2011), MINDSPACE (Dolan, Hallsworth, Halpern, King, & Vlaev, 2010) and EAST (Service et al., 2014)), my role at PHEBI involved applying behavioural science to topics of public health concern. Working in the key public health areas of diet and obesity and sexual health, I synthesised the team's research to help inform policy and practice. This involved trial management, data analysis, liaising with key stake-holders and project partners, overseeing commissioned work and writing reports. I worked on projects looking at how public food environments (such as work cafeterias and vending machines) could be altered to make healthier choices the easier choices (for an example of a report I worked on, see PHE Behavioural Insights Team, 2018). Interventions of this kind focus on altering the "choice architecture" of the small-scale physical environment and "nudging" people towards choosing healthier options (Bucher et al., 2016; G.J. Hollands et al., 2013; Gareth J. Hollands et al., 2017). The environmental focus of this work complimented my PhD research nicely by providing yet more examples of how human behaviour is environmentally-patterned and how environmental quality can be conceptualised and operationalised in yet another different way.

My time at PHEBI also allowed me to focus on other aspects of reproductive and sexual health. I have been providing community-based sexual health outreach and HIV testing since the beginning of my Masters in Reproductive & Sexual Health Research. Just as there are socioeconomic gradients in breastfeeding, this front-line work has highlighted other health disparities, namely those that exist in both access to and provision of sexual health services in this country. Community outreach workers play a key role in improving the sexual health of hard to reach populations (a topic I have blogged about[12]). I have always been interested in sexual behaviour as well as reproductive and parenting behaviour, and so enjoyed working on HIV-related research at PHE. Conducting the analysis and write-up of a randomized controlled text message trial to improve England's HIV self-sampling service was a great detour into the sexual health side of my interests. The trial looked at how simple wording changes to text messages could encourage people to complete and return their home sampling kits. We found that the return rate was 4% higher in the group that received behaviourally informed primer and reminder messages compared to the standard service messages (L.J. Brown, Tan, Guerra, Naidoo, & Nardone, 2018). I presented the trial's findings at conferences held by the UK Society for Behavioural Medicine and HIV Prevention England, providing valuable experience in talking to different research, practice and policy audiences.

My research has also expanded from breastfeeding, a key indicator of parental investment, to age at menarche, a key indicator of pubertal development and reproductive effort, and from high-income countries to low and middle income countries. This is through my work on a project with Dr Tiziana Leone at LSE. The project aims to highlight major gaps in knowledge linking literature from social epidemiology, demography, population health, life course studies, reproductive and mental health as well as bio-demography. I am reviewing the existing literature and all Demographic and Health Surveys (DHS) that have asked the question on age at first period to review the evidence on the determinants and timing of age at menarche in low and middle income countries. I am further increasing my knowledge of the health challenges facing low and middle income countries through my teaching role at King's. There I design and deliver seminars to second year undergraduates in Global Health & Social Medicine for the module Key Concepts in Global Health under the direction of Dr Mauricio Avendano Pabon.

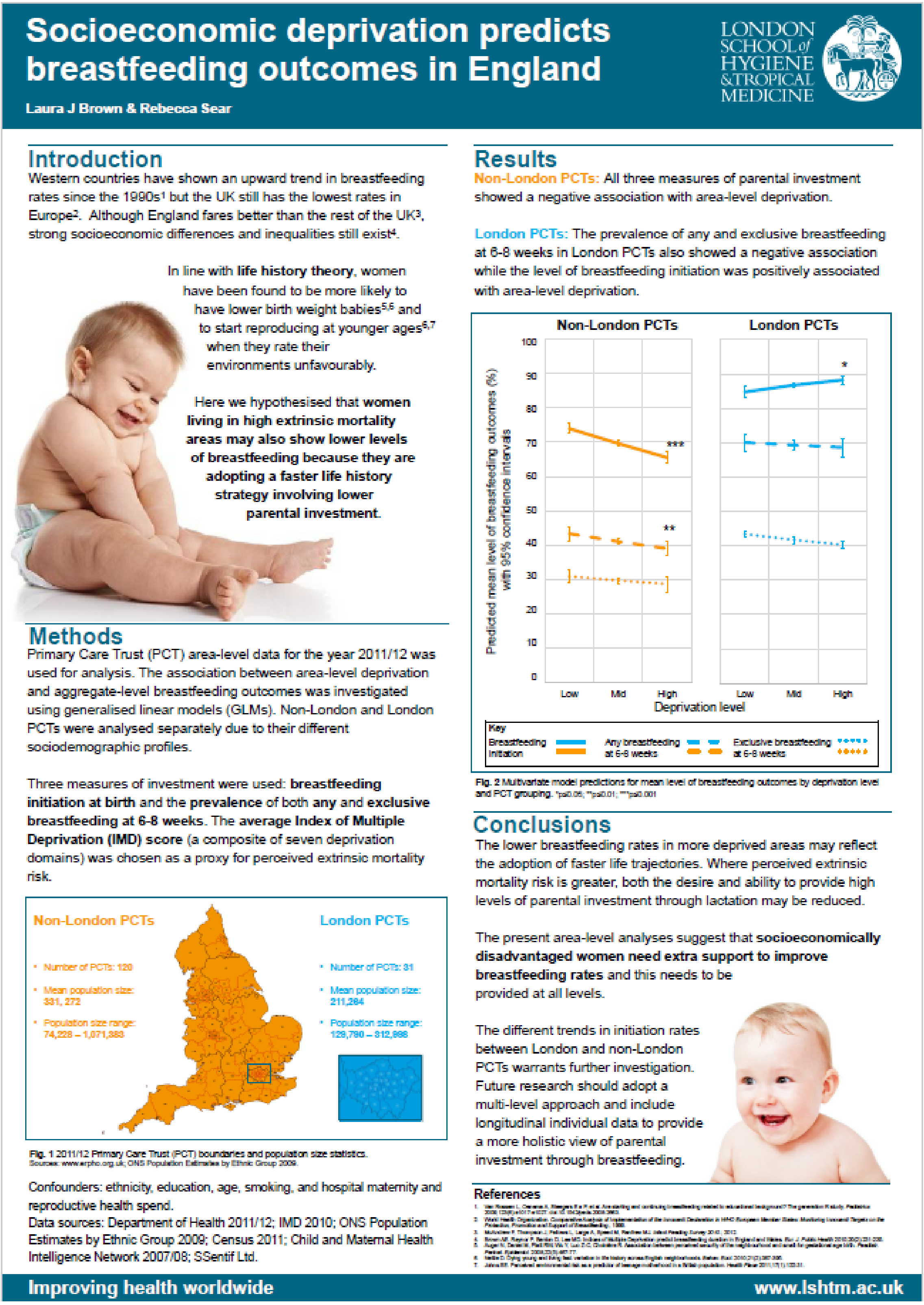
[12] https://laurajbrown88.wixsite.com/ljbrown/single-post/2016/08/25/The-role-of-community-outreach-workers-in-improving-the-sexual-health-of-hard-to-reach-populations

As I have already discussed in Chapter Two, my lactation consultant training and breastfeeding support group volunteering helped to give me an idea of the lived experience behind breastfeeding statistics. Formal fieldwork was not however part of my PhD: instead of focus groups, interviews and ethnographies, my fieldwork took the form of deciphering complex datasets. I have now however gained some first-hand fieldwork experience by working on a trial in secondary schools looking at how a new curriculum resources impacts young people's attitudes, knowledge and behaviour regarding teenage pregnancy and young people's sexual relationships. I visited secondary schools in Greater London to collect baseline data and as a Lead Fieldworker was additionally tasked with providing information sessions to students one week prior to data collection, managing the other fieldworkers on site during data collection visits, and coding open text survey responses.

The last four years have provided a wealth of different skills and experiences and have consolidated my passion for reducing health inequalities through research, teaching and front-line community work. My time at Public Health England has given me an insight into the policy side of research. Academic research was both commissioned and synthesised to produce evidence to shape both local and national policy. This has influenced how I see my own academic research, and the policy implications of my findings.

E. RESEARCH POSTERS

E1. European Human Behaviour and Evolution Association Conference, Helsinki, Finland, 2015



Socioeconomic deprivation predicts breastfeeding outcomes in England

LONDON SCHOOL of HYGIENE &TROPICAL MEDICINE

Laura J Brown & Rebecca Sear

Introduction

Western countries have shown an upward trend in breastfeeding rates since the 1990s[1] but the UK still has the lowest rates in Europe[2]. Although England fares better than the rest of the UK[3], strong socioeconomic differences and inequalities still exist[4].

In line with **life history theory**, women have been found to be more likely to have lower birth weight babies[5,6] and to start reproducing at younger ages[6,7] when they rate their environments unfavourably.

Here we hypothesised that **women living in high extrinsic mortality areas may also show lower levels of breastfeeding because they are adopting a faster life history strategy involving lower parental investment.**

Methods

Primary Care Trust (PCT) area-level data for the year 2011/12 was used for analysis. The association between area-level deprivation and aggregate-level breastfeeding outcomes was investigated using generalised linear models (GLMs). Non-London and London PCTs were analysed separately due to their different sociodemographic profiles.

Three measures of investment were used: **breastfeeding initiation at birth** and the prevalence of both **any** and **exclusive breastfeeding at 6-8 weeks**. The **average Index of Multiple Deprivation (IMD) score** (a composite of seven deprivation domains) was chosen as a proxy for perceived extrinsic mortality risk.

Non-London PCTs

- Number of PCTs: 120
- Mean population size: 331, 272
- Population size range: 74,228 – 1,071,383

London PCTs

- Number of PCTs: 31
- Mean population size: 211,284
- Population size range: 129,790 – 312,988

Fig. 1 2011/12 Primary Care Trust (PCT) boundaries and population size statistics.
Sources: www.erpho.org.uk; ONS Population Estimates by Ethnic Group 2009.

Confounders: ethnicity, education, age, smoking, and hospital maternity and reproductive health spend.
Data sources: Department of Health 2011/12; IMD 2010; ONS Population Estimates by Ethnic Group 2009; Census 2011; Child and Maternal Health Intelligence Network 2007/08; SSentif Ltd.

Results

Non-London PCTs: All three measures of parental investment showed a negative association with area-level deprivation.

London PCTs: The prevalence of any and exclusive breastfeeding at 6-8 weeks in London PCTs also showed a negative association while the level of breastfeeding initiation was positively associated with area-level deprivation.

Fig. 2 Multivariate model predictions for mean level of breastfeeding outcomes by deprivation level and PCT grouping. *p≤0.05; **p≤0.01; ***p≤0.001

Conclusions

The lower breastfeeding rates in more deprived areas may reflect the adoption of faster life trajectories. Where perceived extrinsic mortality risk is greater, both the desire and ability to provide high levels of parental investment through lactation may be reduced.

The present area-level analyses suggest that **socioeconomically disadvantaged women need extra support to improve breastfeeding rates** and this needs to be provided at all levels.

The different trends in initiation rates between London and non-London PCTs warrants further investigation. Future research should adopt a multi-level approach and include longitudinal individual data to provide a more holistic view of parental investment through breastfeeding.

References

1. [illegible]
2. [illegible]
3. [illegible]
4. [illegible]
5. [illegible]
6. [illegible]
7. [illegible]

Improving health worldwide www.lshtm.ac.uk

Are mothers less likely to initiate breastfeeding in harsh environments in the UK? A life history analysis.

Laura J Brown & Rebecca Sear

Department of Population Health, London School of Hygiene and Tropical Medicine, Keppel Street, London WC1E 7HT, UK

LONDON SCHOOL of HYGIENE &TROPICAL MEDICINE

Introduction

Life history theory predicts that parental investment may be lower in harsh environments[1-3]. Using breastfeeding initiation as a measure of parental investment we test whether environmental quality is correlated with the likelihood of breastfeeding initiation in the UK's Millennium Cohort Study. We then go on to determine whether environmental quality influences the known socioeconomic status (SES) gradient in breastfeeding in the UK, where lower SES is associated with lower rates of breastfeeding[4].

Methods

We ran logistic regression models to explore the associations between environmental quality, SES and breastfeeding initiation. We used factor analysis on physical and sociocultural variables to create both an objective (based on observer-rated neighbourhood assessments) and a subjective (based on respondent opinions) measure of environmental quality.

Results

	Objective OR (CI)*	Objective Global p	Subjective OR (CI)*	Subjective Global p
Environmental quality[1]				
Poor quality	1.00 (base)		1.00 (base)	
Mid quality	1.26 (1.10 – 1.44)***	0.0000	0.96 (0.84 – 1.10)	0.7134
High quality	1.53 (1.30 – 1.81)***		0.94 (0.81 – 1.09)	
Job status (NS-SEC)[1]				
Not applicable	1.00 (base)		1.00 (base)	
Routine and manual	1.21 (0.93 – 1.57)		1.22 (0.94 – 1.58)	
Intermediate	1.46 (1.09 – 1.96)*	0.0000	1.53 (1.13 – 2.06)**	0.0000
Higher managerial, administrative, professional	1.94 (1.43 – 2.63)***		2.06 (1.51 – 2.81)***	
Income (OECD equivalised quintiles)[1]				
Lowest	1.00 (base)		1.00 (base)	
Second	1.20 (1.02 – 1.40)*		1.25 (1.07 – 1.47)**	
Middle	1.42 (1.20 – 1.68)***	0.0000	1.56 (1.32 – 1.84)***	0.0000
Fourth	1.57 (1.29 – 1.91)***		1.80 (1.49 – 2.17)***	
Highest	1.78 (1.36 – 2.32)***		2.10 (1.62 – 2.72)***	
Education (highest qualification)[1]				
None	1.00 (base)		1.00 (base)	
Level 1 or 2	1.58 (1.34 – 1.85)***		1.61 (1.37 – 1.90)***	
Levels 3 to 5 (inc. others and overseas)	2.11 (1.76 – 2.53)***	0.0000	2.20 (1.84 – 2.64)***	0.0000
Level 6 plus	4.26 (3.39 – 5.33)***		4.45 (3.54 – 5.59)***	
SES (composite measure)[2]				
Very low	0.63 (0.50 – 0.78)***		0.61 (0.50 – 0.76)***	
Low	1.00 (base)	0.0000	1.00 (base)	0.0000
Middle	1.60 (1.39 – 1.85)***		1.72 (1.49 – 1.98)***	
High	3.49 (2.93 – 4.15)***		4.06 (3.43 – 4.82)***	

Table 1 Environmental quality and SES associations with breastfeeding initiation.
Analyses restricted to natural mothers still living with baby and to singleton births. Models controlled for time at current address, baby's birthweight, maternal age and parity, ethnicity, immigration, acculturation status and urbanicity. NS-SEC: National Statistics Socio-economic Classification. OECD: Organisation for Economic Co-operation and Development. 1: Model with all three separate SES measures included; n=10,998. 2: Model with only composite measure included; n=11,009. If partnered, highest of mother's and partner's SES used. *p≤0.05; **p≤0.01; ***p≤0.001

Results

As predicted, objective environmental quality was significantly associated with breastfeeding initiation: women living in poorer quality environments had lower probabilities of breastfeeding initiation. Subjective environmental quality, however, was not significantly associated with breastfeeding initiation after controlling for potentially confounding variables.

Environmental quality and SES independently predicted breastfeeding initiation. Environmental quality had more of an effect on breastfeeding initiation for low SES women than high SES women and living in a high quality environment seems to offset some of the negative influence of low SES on breastfeeding initiation.

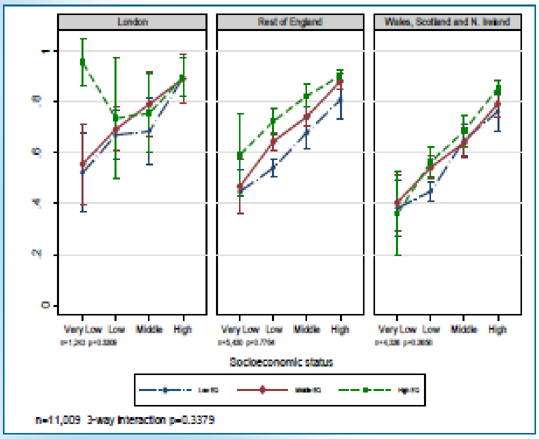


Fig. 1 SES differentials in breastfeeding initiation by objective environmental quality and location in the UK. EQ: environmental quality. NB: Three-way interaction between objective environmental quality, SES and location was significant for job status, education and income but not when composite SES measure was used. Composite SES measure used here for illustrative simplicity.

Although environmental quality did not significantly interact with SES to influence breastfeeding initiation, significant three-way interactions were found between SES, objective environmental quality and location (job status p=0.0419; education p=0.0205; income p=0.0052) .

Conclusions

Our results supported the hypothesis that breastfeeding rates would be lower in harsh environments, though only when objective, not subjective, measures of environmental quality were used. We further found somewhat complex associations between environmental quality, SES, location and breastfeeding initiation. These suggest firstly that both individual condition and environmental quality influence breastfeeding initiation, and secondly that other contextual factors also have an important role to play.

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